HIGHWAY CONSTR

PART II

MERICAN SCHOOL

HIGHWAY CONSTRUCTION

PART II

INSTRUCTION PAPER

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HIGHWAY CONSTRUCTION

PART II

CITY STREETS AND HIGHWAYS

The first work requiring the skill of the engineer is the laying out of town sites properly, especially with reference to the future requirements of a large city, where any such possibility exists. Few if any of our large cities were so planned. The same principles, to a limited extent, are applicable to all towns or cities. The topography of the site should be studied carefully, and the street lines adapted to it. These lines should be laid out systematically, with a view to convenience and comfort, and also with reference to economy of construction, future sanitary improvements, grades, and drainage.

Arrangement of City Streets. Generally, the best method of laying out streets is in straight lines, with frequent and regular intersecting streets, especially for the business parts of a city. When there is some centrally located structure, such as a courthouse, city hall, market, or other prominent building, it is very desirable to have several diagonal streets leading thereto. In the residence portions of cities, especially if on hilly ground, curves may replace straight lines with advantage, by affording better grades at less cost of grading, and by improving property through avoiding heavy embankments or cuttings.

Width of Streets. The width of streets should be proportioned to the character of the traffic that will use them. No rule can be laid down by which to determine the best width of streets; but it may be said safely that a street which is likely to become a commercial thoroughfare should have a width of not less than 120 feet between the building lines—the carriage-way 80 feet wide, and the sidewalks each 20 feet wide.

In streets occupied entirely by residences a carriage-way 32 feet wide will be ample, but the width between the building lines may be

as great as desired. The sidewalks may be any amount over 10 feet which fancy dictates. Whatever width is adopted for them, not more of it than 8 feet need be paved, the remainder being occupied with grass and trees.

Street Grades. The grades of city streets depend upon the topography of the site. The necessity of avoiding deep cuttings or high embankments which seriously would affect the value of adjoining property for building purposes, often demands steeper grades than are permissible on country roads. Many cities have paved streets on 20 per cent grades. In establishing grades through unimproved property, they usually may be laid with reference to securing the most desirable percentage within a proper limit of cost. But when improvements already have been made and have been located with reference to the natural surface of the ground, the matter of giving a desirable grade without injury to adjoining property frequently is one of extreme difficulty. In such cases it becomes a question of how far individual interests shall be sacrificed to the general good. There are, however, certain conditions which it is important to bear in mind: (1) That the longitudinal crown level should be sustained uniformly from street to street intersection, whenever practicable. (2) That the grade should be sufficient to drain the surface. (3) That the crown levels at all intersections should be extended transversely, to avoid forming a depression at the junction.

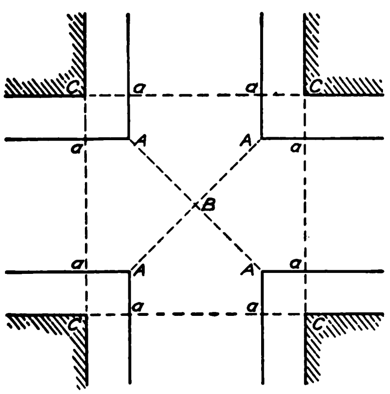


Fig. 71. Diagram Showing Arrangement of Grades at Street Intersections

Arrangements of Grades at Street Intersections. The best arrangement for intersections of streets when either or both have much inclination is a matter which requires careful consideration and upon which much diversity of opinion exists. No hard or fast rule can be laid down; each will require special adjustment. The best and simplest method is to make level the rectangular space *aaaaaaaa*, Fig. 71, with a rise of one-half inch in 10 feet from *AAAA* to *B*,

placing gulleys at $AAAA$ and the catch basins at ccc. When this method is not practicable, adopt such a grade (but one not exceeding $2\frac{1}{2}$ per cent) that the rectangle $AAAA$ shall appear to be nearly level; but to secure this it must have actually a considerable dip in the direction of the slope of the street. If steep grades are continued across intersections, they introduce side slopes in the streets thus crossed, which are troublesome, if not dangerous, to vehicles turning the corners, especially the upper ones. Such intersections

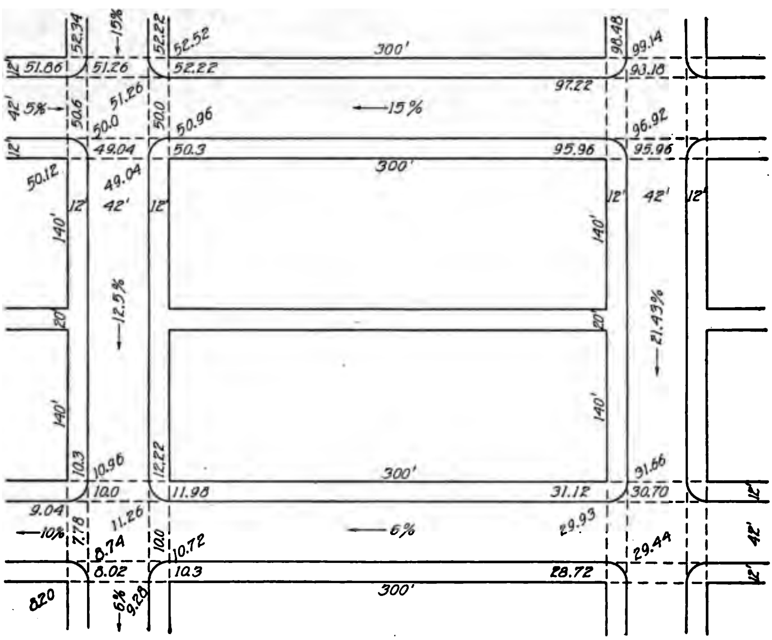


Fig. 72. Diagram Showing Arrangement of Intersections for Steep Grades in Duluth, Minnesota

are especially objectionable in rainy weather. The storm water will fall to the lowest point, concentrating a large quantity of water at two receiving basins, which, with a broken grade, could be divided among four or more basins.

Fig. 72 shows the arrangement of intersections in steep grades adapted for the streets of Duluth, Minnesota. From this it will be seen that at these intersections the grades are flattened to 3 per cent for the width of the roadway of the intersecting streets, and that the grade of the curbs is flattened to 8 per cent for the width of the

intersecting sidewalks. Grades of less amount on roadway or sidewalk are continuous. The elevation of block corners is found by adding together the curb elevations at the faces of the block corners, and 2½ per cent of the sum of the widths of the two sidewalks at the corner, and dividing the whole by two. This gives an elevation equal to the average elevation of the curbs at the corners, plus an average rise of 2½ per cent across the width of the sidewalk.

"Accommodation summits" have to be introduced between street intersections in two general cases: (1) in hilly localities, to avoid excessive excavation; and (2) when the intersecting streets are level or nearly so, for the purpose of obtaining the fall necessary for surface drainage.

The elevation and location of such a summit may be calculated as follows: Let A, Fig. 73, be the elevation of the highest corner;

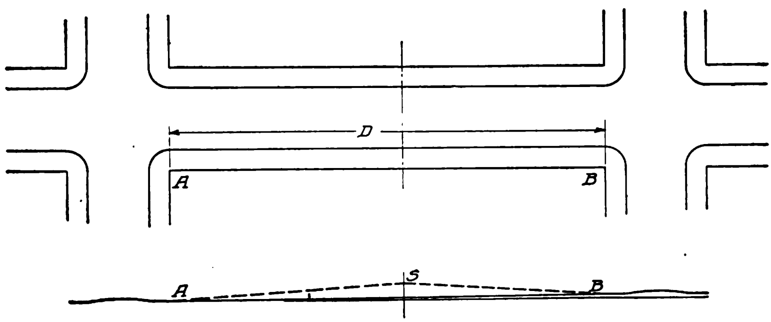


Fig. 73. Diagrams for Calculating "Accommodation Summits" between Street Intersections

B, the elevation of the lowest corner; D, the distance from corner to corner; and R, the rate of the accommodation grade. The elevation of the summit is equal to

$$\frac{D \times R + A + B}{2}$$

The distance from A or B is found by subtracting the elevation of either A or B from this quotient, and dividing the result by the rate of grade. Or the summit may be located mechanically by specially prepared scales. Prepare two scales divided to correspond to the rate of grade; that is, if the rate of grade be 1 foot per 100 feet, then one division of the scale should equal 100 feet on the map scale,

These divisions may be subdivided into tenths. One scale should read from right to left, and one from left to right.

To use the scales, place them on the map so that their figures correspond with the corner elevations; then, as the scales read in opposite directions, there is of course some point at which the opposite readings will be the same. This point is the location of the summit, and the figures read off the scale give its elevation. If the difference in elevation of the corners is such as not to require an intermediate summit for drainage, it will be apparent as soon as the scales are placed in position.

When an accommodation summit is employed, it should be formed by joining the two straight grade lines by a vertical curve, as described in Part I. The curve should be used both in the crown of the street and in the curb and footpath.

Where the grade is level between intersections, sufficient fall for surface drainage may be secured without the aid of accommodation summits, by arranging the grades as shown in Fig. 74. The curb is

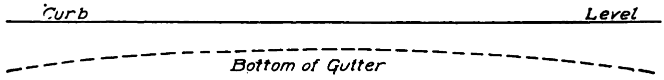


Fig. 74. Diagram Showing Arrangement of Grades to Avoid "Accommodation Summits"

set level between the corners; a summit is formed in the gutter; and receiving basins are placed at each corner.

Transverse Grade. In its transverse grade the street should be level; that is, the curbs on opposite sides should be at the same level,

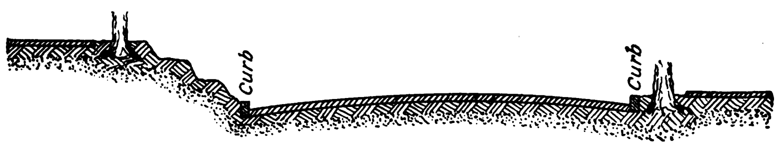


Fig. 75. Street with Unequal Transverse Grade but with Level Street

and the street crown rise equally from each side to the center. But in hillside streets this condition cannot be fulfilled always, and opposite sides of the street may differ as much as 5 feet. In such cases the engineer will have to use his discretion as to whether he shall adopt a straight slope inclining to the lower side, thus draining

the whole street by the lower gutter, or adopt the three-curb method and sod the slope of the higher side.

In the improvement of old streets with the sides at different levels, much difficulty will be met, especially where shade trees have

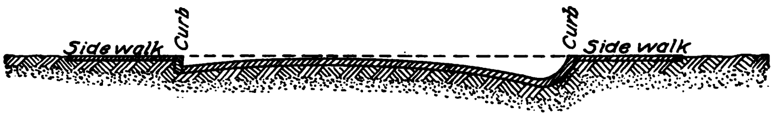


Fig. 76. Street with Unequal Transverse Grade Inclined so as to Drain by Lower Gutter

to be spared. In such cases, recognized methods have to be abandoned, and the engineer will have to adopt methods of overcoming the difficulties in accordance with the conditions and necessities of each particular case. Figs. 75, 76, and 77 illustrate several typical

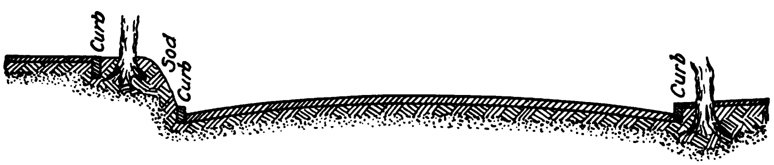


Fig. 77. Street with Unequal Transverse Grade with Three Curbs and Higher Slope Sodded

arrangements in the cases of streets where the opposite sides are at different levels.

Transverse Contour or Crown. The reason for crowning a pavement—i. e., making the center higher than the sides—is to provide for the rapid drainage of the surface. The most suitable form for the crown is the parabolic curve, which may be started at the curb line, or at the edge of the gutter adjoining the carriage-way,

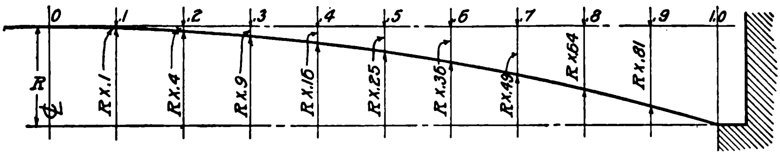


Fig. 78. Method of Obtaining Transverse Contour or Crown of a Road

about one foot from the curb. Fig. 78 shows this form, which is obtained by dividing the abscissa, or width from the center of the street to the gutter, into ten equal parts, and by dropping perpendiculars at each of these divisions, the lengths of which are determined by multiplying the rise at the center by the square of the

TABLE XII

Rise of Pavement Center above Gutter for Different Paving Materials

Paving Material	Proportions of Rise at Center to Width of Carriage-Way
Wood blocks	1 : 100
Stone blocks	1 : 80
Brick	1 : 80
Asphalt	1 : 80

successive values of the abscissas. The amounts thus obtained can be added to the rod readings; and the stakes, set at the proper distance across the street, with their tops at this level, will give the required curve.

The amount of transverse rise, or the height of the center above the gutters, varies with the different paving materials; smooth pavements requiring the least, and rough ones and earth the greatest rise. The rise is generally stated in a proportion of the width of the carriage-way. The most suitable proportions are shown in Table XII.

Drainage of Streets. *Sub-Foundation Drainage.* The sub-foundation drainage of streets cannot be effected by transverse drains, because of their liability to disturbance by the introduction of gas, water, and other pipes.

Longitudinal drains must be depended upon entirely; they may be constructed of the same materials and in the same manner as road drains. The number of these longitudinal drains must depend upon the character of the soil. If the soil is moderately retentive, a single row of tiles or a hollow invert placed under the sewer in the center of the street generally will be sufficient; or two rows of tiles may be employed, one placed outside each curb line. If, on the other hand, the soil is exceedingly wet and the street very wide, four or more lines may be employed. These drains may be permitted to discharge into the sewers of the transverse streets.

Surface Drainage. The removal of water falling on the street surface is provided for by collecting it in the gutters, from which it is discharged into the sewers or other channels by means of catch basins placed at all street intersections and dips in the street grades.

Gutters. The gutters must be of sufficient depth to retain all the water which reaches them and prevent its overflowing on the foot-

path. The depth should never be less than 6 inches, and very rarely need be more than 10 inches.

Catch Basins. Catch basins are of various forms, usually circular or rectangular, built of brick masonry coated with a plaster of Portland cement. Whichever form is adopted, they should fulfill the following conditions:

(1) The inlet and outlet should have sufficient capacity to receive and discharge all water reaching the basin.

(2) The basins should have sufficient capacity below the outlet to retain all sand and road detritus, and prevent its being carried into the sewer.

(3) They should be trapped so as to prevent the escape of sewer gas. (This requirement frequently is omitted, to the detriment of the health of the people.)

(4) They should be constructed so that the pit can be cleaned out easily.

(5) The inlet should be constructed so as not to be choked easily by leaves or dêbris.

(6) They must offer the least possible obstruction to traffic.

(7) The pipe connecting the basin to the sewer should be freed easily of any obstruction.

The bottoms of the basins should be 6 or 8 feet below the street level; and the water level in them should be from 3 to 4 feet lower than the street surface, as a protection against freezing.

The capacity and number of basins will depend upon the area of the surface which they drain.

In streets having level or light longitudinal grades, gullies may be formed along the line of the gutter at such intervals as may be found necessary.

Catch basins usually are placed at the curb line. In several cities, the basin is placed in the center of the street, and connects to inlets placed at the curb line. This reduces the cost of construction and cleaning, and removes from the sidewalk the dirty operations of cleaning the basins.

Catch basins and gully pits require cleaning out at frequent intervals; otherwise the odor arising from the decomposing matter contained in them will be very offensive. No rule can be laid down for the intervals at which the cleaning should be done, but they must

be cleaned often enough to prevent the matter in them from putrefying. There is no uniformity of practice observed by cities in this matter; in some, the cleaning is done but once a year; in others, after every rain-storm; in still others, at intervals of three or four months; while in a few cities the basins are cleaned out once a month.

FOUNDATIONS

The stability, permanence, and maintenance of any pavement depend upon its foundation. If the foundation is weak, the surface soon will settle unequally, forming depressions and ruts. With a good foundation, the condition of the surface will depend upon the material employed for the pavement and upon the manner of laying it.

The essentials necessary to the forming of a good foundation are:

(1) The entire removal of all vegetable, perishable, and yielding matter. It is of no use to lay good material on a bad substratum.

(2) The drainage of the subsoil wherever necessary. A permanent foundation can be secured only by keeping the subsoil dry; for, where water is allowed to pass into and through it, its weak spots will be discovered quickly, and settlement will take place.

(3) The thorough compacting of the natural soil by rolling with a roller of proper weight and shape until there is formed a uniform and unyielding surface.

(4) The placing on the natural soil so compacted of a thickness of an impervious and incompressible material sufficient to cut off all communication between the soil and the bottom of the pavement.

The character of the natural soil over which the roadway is to be built has an important bearing upon the kind of foundation and the manner of forming it; each class of soil will require its own special treatment. Whatever its character, it must be brought to a dry and tolerably hard condition by draining and rolling. Sand and gravels which do not hold water, present no difficulty in securing a solid and secure foundation; clays and soils retentive of water are the most difficult. Clay should be excavated to a depth of at least 8 inches below the bottom of the finished covering; and the space so excavated should be filled in with sand, furnace slag, ashes, coal dust, oyster shells, broken brick, or other materials which are not absorbent of water excessively. A clay soil or one retaining water may be cheaply

and effectually improved by laying cross drains with open joints at intervals of 50 or 100 feet. These drains should be not less than 18 inches below the surface, and the trenches should be filled with gravel. They should be 4 inches in internal diameter, and should empty into longitudinal drains.

Sand and planks, gravel and broken stone successively have been used to form the foundation for pavements; but, although eminently useful materials, their application to this purpose always has been a failure. Being inherently weak and possessing no cohesion, the main reliance for both strength and wear must be placed upon the surface covering. This covering—usually (except in case of sheet asphalt) composed of small units, with joints between them varying from ½ inch to 1½ inches—posesses no elements of cohesion; and under the blows and vibrations of traffic the independent units or blocks will settle and be jarred loose. On account of their porous nature, the subsoil quickly becomes saturated with urine and surface waters, which percolate through the joints; winter frosts upheave them; and the surface of the street becomes blistered and broken up in dozens of places.

Concrete. As a foundation for all classes of pavement (broken stone excepted), hydraulic-cement concrete is superior to any other. When properly constituted and laid, it becomes a solid, coherent mass, capable of bearing great weight without crushing. If it fail at all, it must fail altogether. The concrete foundation is the most costly, but this is balanced by its permanence and by the saving in the cost of repairs to the pavement which it supports. It admits of access to subterranean pipes with less injury to the neighboring pavement than any other, for the concrete may be broken through at any point without unsettling the foundation for a considerable distance around it, as is the case with sand or other incoherent material; and when the concrete is replaced and set, the covering may be reset at its proper level, without the uncertain allowance for settlement which is necessary in other cases.

Thickness of Course. The thickness of the concrete bed must be proportioned by the engineer; it should be sufficient to provide against breaking under transverse strain caused by the settlement of the subsoil. On a well-drained soil, 6 inches will be found sufficient; but in moist and clayey soils, 12 inches will not be excessive. On

such soils a layer of sand or gravel, spread and compacted before placing the concrete, will be found very beneficial.

The proportions of the ingredients required for the manufacture of concrete are ascertained by measuring the voids in each ingredient. The strongest concrete will be produced when the volume of cement is slightly in excess of that required to fill the voids in the sand, and the volume of the combined cement and sand exceeds by about 10 per cent the volume of the voids in the stone or other material used for the aggregate. Concrete frequently is mixed in the arbitrary proportions of 1 part of cement, 3 parts of sand, and 6 parts of stone, and although the results have been satisfactory, the proportions may not be the most economical.

The ingredients of the concrete should be thoroughly mixed with just sufficient water to produce a plastic mass, without any surplus water running from it. After mixing, the concrete should be deposited quickly in place, and brought to a uniform surface and thickness by raking, then tamped until the mortar flushes to the surface, then left undisturbed until set. The surface of concrete laid during dry, warm, weather should be protected from the drying action of the sun while the initial setting is in progress. This may be accomplished by sprinkling with water as frequently as the rate of evaporation demands or by covering it with a layer of damp sand, straw, hay, or canvas. During freezing weather it is customary to suspend the laying of concrete for the reason that alternate freezing and thawing disintegrate it.

Measuring Voids in the Stone and Sand. The simplest method for measuring the voids and one sufficiently accurate for the manufacture of concrete is the "pouring method" in which a suitable vessel of known capacity (usually one cubic foot) is filled with the material, in which it is desired to ascertain the voids. Water then is poured into the vessel until its surface is flush with the surface of the material. The water is measured, and its amount is considered to equal the total of the voids.

STONE-BLOCK PAVEMENTS

Stone blocks commonly are employed for pavements where traffic is heavy. The material of which the blocks are made should possess sufficient hardness to resist the abrasive action of traffic, and

TABLE XIII

Specific Gravity, Weight, Resistance to Crushing, and Absorptive Power of Stones

Material	Specific Gravity		Weight (lb. per cu. ft.)		Resistance to Crushing (lb. per sq. in.)		Percentage of Water Absorbed	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Granite	2.60	2.80	163	176	12,000	35,000	0.066	0.155
Trap	2.86	3.03	178	189	19,000	24,000	0.000	0.019
Sandstone	2.23	2.75	137	170	5,000	18,000	0.410	5.480
Limestone	1.90	2.75	118	175	7,000	20,000	0.200	5.000
Brick, paving	1.95	2.55			10,000	20,000		

sufficient toughness to prevent them from being broken by the impact of loaded wheels. The hardest stones will not give necessarily the best results in the pavement, since a very hard stone usually wears smooth and becomes slippery. The edges of the block chip off, and the upper face becomes rounded, thus making the pavement very rough.

The stone sometimes is tested to determine its strength, resistance to abrasion, etc.; but, as the conditions of use are quite different from those under which it may be tested, such tests are seldom satisfactory. However, examination of a stone as to its structure, the closeness of its grain, its homogeneity, porosity, etc., may assist in forming an idea of its value for use in a pavement. A low degree of permeability usually indicates that the material will not be greatly affected by frost. For data see Table XIII.

Materials. *Granite.* Granite is employed more extensively for stone-block paving than is any other variety of stone; and because of this fact, the term "granite paving" is generally used as being synonymous with stone-block paving. The granite employed should be of a tough, homogeneous nature. The hard, quartz granites usually are brittle, and do not wear well under the blows of horses' feet or the impact of vehicles; granite containing a high percentage of feldspar will be injuriously affected by atmospheric changes; and granite in which mica predominates will wear rapidly on account of its laminated structure. Granite possesses the very important property of splitting in three planes at right angles to one another,

so that paving blocks may readily be formed with nearly plane faces and square corners. This property is called the rift or cleavage.

Sandstones. Sandstones of a close-grained, compact nature often give very satisfactory results under heavy traffic. They are less hard than granite, and wear more rapidly, but do not become smooth and slippery. Sandstones are generally known in the market by the name of the quarry or place where produced as "Medina", "Berea", etc.

Trap Rock. Trap rock, while answering well the requirements as to durability and resistance to wear, is objectionable on account of its tendency to wear smooth and become slippery; it is also difficult to break into regular shapes.

Limestone. Limestone usually has not been successfully employed in the construction of block pavements, on account of its lack of durability against atmospheric influences. The action of frost commonly splits the blocks; and traffic shivers them, owing to the lamination being vertical.

Cobblestone Pavement. Cobblestones bedded in sand possess the merit of cheapness, and afford an excellent foothold for horses; but the roughness of such pavements requires the expenditure of a large amount of tractive energy to move a load over them. Aside from this, cobblestones are entirely wanting in the essential requisites of a good pavement. The stones being of irregular size, it is almost impossible to form a bond or to hold them in place. Under the action of the traffic and frost, the roadway soon becomes a mass of loose stones. Moreover, cobblestone pavements are difficult to keep clean, and very unpleasant to travel over.

Belgian-Block Pavement. Cobblestones were displaced by pavements formed of small cubical blocks of stone. This type of pavement was laid first in Brussels, thence imported to Paris, and from there taken to the United States, where it has been widely known as the "Belgian-block" pavement. It has been largely used in New York City, Brooklyn, and neighboring towns, the material being trap rock obtained from the Palisades on the Hudson River.

The stones, being of regular shape, remain in place better than cobblestones; but the cubical form (usually 5 inches in each dimension) is a mistake. The foothold is bad; the stones wear round; and the number of joints is so great that ruts and hollows are quickly

formed. This pavement offers less resistance to traction than cobblestones, but it is almost equally rough and noisy.

Granite-Block Pavement. The Belgian block gradually has been displaced by the introduction of rectangular blocks of granite. Blocks of comparatively large dimensions were employed at first. They were from 6 to 8 inches in width on the surface, from 10 to 20 inches in length, with a depth of 9 inches. They merely were placed in rows on the subsoil, perfunctorily rammed, the joints filled with sand, and the street thrown open to traffic. The unequal settlement of the blocks, the insufficiency of the foothold, and the difficulty of cleansing the street, led to the gradual development of the latest type of stone-block pavement, which consists of narrow, rectangular blocks of granite, properly proportioned, laid on an unyielding and impervious foundation, with the joints between the blocks filled with an impermeable cement.

Experience has proved beyond doubt that this latter type of pavement is the most enduring and economical for roadways subjected to heavy and constant traffic. Its advantages are many, while its defects are few.

Advantages.

(1) Adapted to all grades.

(2) Suits all classes of traffic.

(3) Exceedingly durable.

(4) Foothold, fair.

(5) Requires but little repair.

(6) Yields but little dust or mud.

(7) Facility for cleansing, fair.

Defects.

(1) Under certain conditions of the atmosphere, the surface of the pavement becomes greasy and slippery.

(2) The incessant din and clatter occasioned by the movement of traffic is an intolerable nuisance; it is claimed by many physicians that the noise injuriously affects the nerves and health of persons who are obliged to live or do business in the vicinity of streets so paved.

(3) Horses constantly employed upon it soon suffer from the continual jarring produced in their legs and hoofs, and quickly wear out.

(4) The discomfort of persons riding over the pavement is very great, because of the continual jolting to which they are subjected.

(5) If stones of an unsuitable quality are used—for example, those that polish—the surface quickly becomes slippery and exceedingly unsafe for travel.

Blocks. *Size and Shape.* The proper size of blocks for paving purposes has been a subject of much discussion, and a great variety of forms and dimensions are to be found in all cities.

For stability, a certain proportion must exist between the depth, the length, and the breadth. The depth must be such that when the wheel of a loaded vehicle passes over one edge of the upper surface of a block, the block will not tend to tip up. The resultant direction of the pressure of the load and adjoining blocks always should tend to depress the whole block vertically; where this does not happen, the maintenance of a uniform surface is impossible. To fulfill this requirement, it is not necessary to make the block more than 6 inches deep.

Width. The maximum width of blocks is controlled by the size of horses' hoofs. To afford good foothold to horses drawing heavy loads, it is necessary that the width of each block, measured along the street, shall be the least possible consistent with stability. If the width be great, a horse drawing a heavy load, attempting to find a joint, slips back, and requires an exceptionally wide joint to pull him up. It is therefore desirable that the width of a block shall not exceed 3 inches; or that four blocks, taken at random and placed side by side, shall not measure more than 14 inches.

Length. The length, measured across the street, must be sufficient to break joints properly, for two or more joints in line lead to the formation of grooves. For this purpose the length of the block should be not less than 9 inches nor more than 12 inches.

Form. The blocks should be well squared, and must not taper in any direction; sides and ends should be free from irregular projections. Blocks that taper from the surface downwards (wedge-shaped) should not be permitted in the work; but if any are allowed, they should be set with the widest side down.

Manner of Laying Blocks. The blocks should be laid in parallel courses, with their longest side at right angles to the axis of the street, and the longitudinal joints broken by a lap of at least 2 inches,

Figs. 79 and 80. The reason for this is to prevent the formation of longitudinal ruts, which would happen if the blocks were laid lengthwise. Laying blocks obliquely and "herringbone" fashion has been tried in several cities, with the idea that the wear and formation of ruts would be reduced by having the vehicle cross the blocks diagonally. The method has failed to give satisfactory results; the wear was irregular and the foothold defective; the difficulty of construction was increased by reason of labor required to form the triangular joints; and the method was wasteful of material.

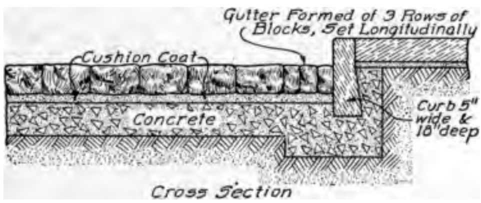


Fig. 79. Section Showing Method of Laying Stone-Block Pavement

The gutters should be formed by three or more courses of block, laid with their length parallel to the curb.

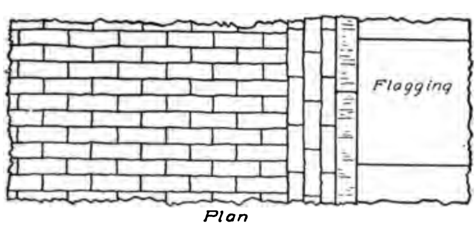


Fig. 80. Plan of Stone-Block Pavement Showing Method of Laying Blocks

At junctions or intersections of streets, the blocks should be laid diagonally from the center, as shown in Fig. 81. The reasons for this are: (1) to prevent the traffic crossing the intersection from following the longitudinal joints and thus forming depressions and ruts; (2) laid in this manner, the blocks afford a more secure foothold for horses turning the corners. The ends of the diagonal blocks where they abut against the straight blocks, must be cut to the required bevel.

The blocks forming each course must be of the same depth, and no deviation greater than $\frac{1}{4}$ inch should be permitted. The blocks should be assorted as they are delivered, and only those corresponding in depth and width should be used in the same course. The better method would be to gage the blocks at the quarry. This would lessen the cost considerably; it would avoid also the inconvenience to the public due to the stopping of travel because of the rejection of defective material on the ground. This method undoubt-

edly would be preferable to the contractor, who would be saved the expense of handling unsatisfactory material; and it also would leave the inspectors free to pay more attention to the manner in which the work of paving is performed.

The accurate gaging of the blocks is a matter of much importance. If good work is to be executed, the blocks, when laid, must be in parallel and even courses; and if the blocks are not gaged accurately to one uniform size, the result will be a badly paved street, with the courses running unevenly. The cost of assorting blocks into lots of uniform width, after delivery on the street, is far in excess of any

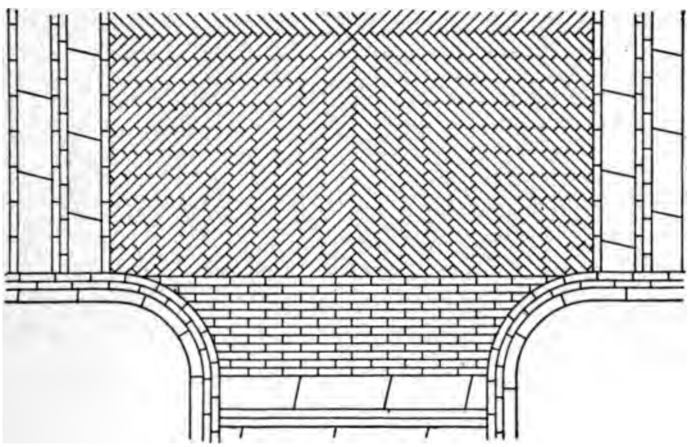


Fig. 81. Diagram Showing Method of Laying Stone Blocks at Intersection of Streets

additional price which would have to be paid for accurate gaging at the quarry.

Foundation. The foundation of the blocks must be solid and unyielding. A bed of hydraulic-cement concrete is the most suitable, and its thickness must be regulated according to the traffic; the thickness, however, should not be less than 4 inches, and need not be more than 9 inches. A thickness of 6 inches will sustain traffic of 600 tons per foot of width.

Cushion Coat. Between the surface of the concrete and the base of the blocks, there must be placed a cushion coat formed of an incompressible but mobile material, the particles of which readily will adjust themselves to the irregularities of the bases of the blocks

and transfer the pressure of the traffic uniformly to the concrete below. A layer of dry, clean sand 1 inch to 2 inches thick forms an excellent cushion coat. Its particles must be of such fineness as to pass through a No. 8 screen; if the sand is coarse and contains pebbles, it will not adapt itself to the irregularities of the bases of the blocks; hence the blocks will be supported at a few points only, and unequal settlement will take place when the pavement is subjected to the action of traffic. The sand also must be perfectly free from moisture, and artificial heat must be used to dry it if necessary. This requirement is an absolute necessity. There should be no moisture below the blocks when laid; nor should water be allowed to penetrate below the blocks; if such happens, the effect of frost will be to upheave the pavement and crack the concrete.

Where the best is desired without regard to cost, a layer of asphaltic cement ½ inch thick may be substituted for the sand, with superior and very satisfactory results.

Laying Blocks. The blocks should be laid stone to stone, so that the joint may be of the least possible width; wide joints cause increased wear and noise, and do not increase the foothold. The courses should be commenced on each side and should be worked toward the middle; and the last stone should fit tightly.

Ramming. After the blocks have been set, they should be well rammed down; and the stones which sink below the general level should be taken up and replaced with a deeper stone or brought to level by increasing the sand bedding.

The practice of workmen invariably is to use the rammer so as to secure a fair surface. This does not give the result intended to be secured, but brings each block to an unyielding bearing. The result of such a surfacing process is to produce an unsightly and uneven roadway when the pressure of traffic is brought upon it. The rammer used should weigh not less than 50 pounds and have a diameter of not less than 3 inches.

Fillings for Joints. All stone-block pavements depend for their waterproof qualities upon the character of the joint filling. Joints filled with sand and gravel of course are pervious. A grout of lime or cement mortar does not make a permanently waterproof joint; it becomes disintegrated under the vibration of traffic. An impervious joint can be made only by employing a filling made from bituminous

or asphaltic material; this renders the pavement more impervious to moisture, makes it less noisy, and adds considerably to its strength.

Bituminous Cement for Joint Filling. The bituminous materials employed are: (1) coal tar having a specific gravity between 1.23 and 1.33 at 60 degrees Fahrenheit, a melting point between 120 and 130 degrees Fahrenheit, and containing not over 30 per cent of free carbon. (2) asphalt, either natural or artificial, entirely free from coal tar or any product of coal-tar distillation, and containing not less than 98 per cent of pure bitumen soluble in carbon bisulphide. Of the total amount soluble in carbon bisulphide, 98.5 per cent must be soluble in carbon tetrachloride. The penetration, when tested by the Dow method, must be not greater than 110, at 115 degrees Fahrenheit, and at 77 degrees Fahrenheit must range between 25 and 60. The specific gravity at 60 degrees Fahrenheit must not be more than 1.00.

The mode of applying the coal-tar filler is as follows: After the blocks are laid, gravel heated to about 250 degrees Fahrenheit is spread over the surface and swept into the joints until they are filled to a depth of about 2 inches. The blocks then are rammed. The coal-tar filler heated to a temperature between 250 and 300 degrees Fahrenheit is poured into the joints until they are about half filled, hot gravel is swept in until it reaches to within ½ inch of the surface, and hot filler is then poured in until it is flush with the surface of the blocks; after this sufficient hot gravel is applied to the joints to conceal the filler.

In applying the coal-tar filler it is essential that both the gravel and filler are heated sufficiently. Otherwise the filler will be chilled and will not flow to the bottom of the joint, but will form a thin layer near the surface, which under the action of frost and the vibration of traffic, will be cracked and broken up quickly; the gravel will settle, and the blocks will be jarred loose, causing the surface of the pavement to become a series of ridges and hollows. The filler should not be applied during a rainfall or while the blocks are wet or damp, for such a condition would prevent the filler from adhering to the blocks. The asphalt filler is heated to a temperature between 400 and 450 degrees Fahrenheit and poured into the joints until they are entirely filled.

Hydraulic-Cement Filler is composed of equal parts of Portland cement and sharp sand mixed with clean fresh water to a suitable consistency. The joints between the blocks are filled to a depth of 2 inches with gravel, and the blocks are rammed, after which the filler is poured into the joints until they are filled flush with the surface of the blocks. In dry weather the blocks should be moistened by sprinkling with water before applying the filler. After the filler has taken its initial set, the whole surface of the pavement is covered with a layer of sand about ½ inch thick and if the weather is dry and warm it is sprinkled with water daily for three days. Traffic is not permitted to use the pavement until at least seven days after completion.

Stone Pavement on Steep Grades. Stone blocks may be employed on all practicable grades, but on grades exceeding 10 per cent, cobblestones afford a better foothold than blocks. The cobblestones should be of uniform length, the length being at least twice the breadth—say stones 6 inches long and 2½ inches to 3 inches in diameter.

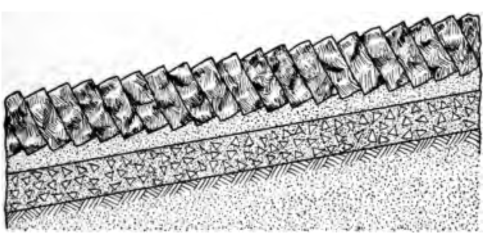


Fig. 82. Laying Stone Pavement on Steep Grades by Tilting Blocks

These should be set on a concrete foundation, laid stone to stone, and the interstices filled with cement grout or bituminous cement; or a bituminous-concrete foundation may be employed and the interstices between the stones may be filled with asphaltic paving cement. Should stone blocks be preferred, they must be laid, when the grade exceeds 5 per cent, with a serrated surface, by either of the methods shown in Figs. 82 and 83. The method shown in Fig. 82 consists in slightly tilting the blocks on their bed so as to form a series of ledges or steps, which will insure a good foothold for horses' hoofs. The

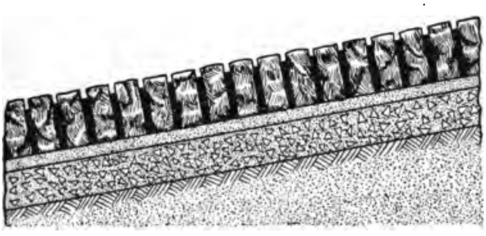


Fig. 83. Laying Stone Pavement on Steep Grades by Separating Blocks and Filling with Grout

method shown in Fig. 83 consists in placing between the rows of stones a course of slate, or strips of creosoted wood, rather less than 1 inch in thickness and about 1 inch less in depth than the blocks; or the blocks may be spaced about 1 inch apart, and the joints filled with a grout composed of gravel and cement. The pebbles of the gravel should vary in size between ¼ inch and ¾ inch.

BRICK PAVEMENTS

A brick pavement consists of vitrified bricks laid on a suitable concrete foundation, Fig. 84.

Qualifications of Brick. The qualities essential to a good paving brick are the same as for any other paving material, viz, hardness, toughness, and ability to resist the disintegrating effects

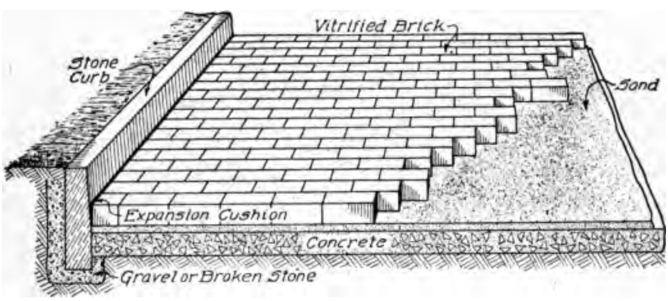


Fig. 84. Section Showing Method of Laying Vitrified Brick Pavement

of water and frost. These qualities are imparted to the brick by a process of annealing, through which the clay is brought to the point of fusion, and the heat then gradually reduced until the kiln is cold.

Composition. The material from which is made the majority of the brick used for paving is a shale. Shales are indurated clays with a laminated structure and the appearance of slate, and occur in stratified beds. The average composition of the shales that have proved satisfactory for the manufacture of paving brick is shown in Table XIV.

An excess of silica causes brittleness; or an excess of alumina causes shrinking, cracking, and warping. Iron renders the clay fusible and makes the brick more homogeneous. Lime in the form of silicate is valuable as a flux, but in the form of carbonate it will

TABLE XIV

Average Composition of Shales for Paving-Brick Manufacture

CONSTITUENTS	PROPORTIONAL PART (per cent)
(Non-Fluxing)	
Silica	56.0
Alumina	22.0
Water and loss on ignition	7.0
Moisture	2.0
(Fluxing)	
Sesquioxide of iron	7.0
Lime	1.0
Magnesia	1.0
Alkalies	4.0
Total	100.0

decrease the strength of the brick; at a high temperature it is changed into caustic lime, which, while rendering the clay more fusible, will absorb moisture upon exposure to the weather and thus cause the brick to disintegrate. Magnesia exerts but little influence on the character of the brick. The alkalies in small quantities render the clay fusible.

Color. The color of the clay is of no practical importance; it is due to the presence of the metallic oxides and organic substances. Iron produces bricks which are either red, yellow, or blue, according to the quantity present and the degree of heat; some organic substances produce a blue, bluish-gray, or black color.

The color of the brick is governed partly by the color of the clay, by the temperature of burning, by the kind of fuel used, and by the sand that is used to prevent the brick from sticking to the dies or to each other in the kiln.

Manufacture. In the manufacture of the brick, the shale is crushed usually in dry paws and then passed through a 4-mesh or an 8-mesh screen. The screened material is mixed with water in a pug mill to the required consistency. The finer the material is crushed and the more thoroughly it is worked or tempered in the mill, the more uniform and better the brick is.

The plastic clay, in the "stiff-mud" process, as it leaves the pug mill is forced by an auger through a die which forms a bar of stiff

clay of the desired dimensions, and this is cut by an automatic cutter into bricks of the size required. The bricks then, in some factories, are repressed in a die, during which the edges of the brick are rounded and the lugs, grooves, and trade-mark stamped on the sides. When repressing is not practiced, the bar of clay as it comes from the pug mill is cut by wires, the brick being called "wire-cut lug" brick.

The bricks, made by either method, are placed in a heated chamber to dry, this requiring from 18 to 60 hours according to the clay, temperature, and plant arrangement. When dry the bricks are stacked in the kiln, which is usually of the down-draft type with furnaces built in the outer walls. The bottom of the kiln is perforated to allow the gases to pass through to the flues placed below the floor and connected to the chimney. The heat from the furnace passes upward into the kiln, then downward through the bricks into the flues and thence to the chimney. At the beginning of the burning the heat is applied slowly to drive off the contained water without cracking the bricks. When the dryness of the smoke indicates the absence of moisture in the bricks, the fires are gradually increased until the temperature throughout the kiln is from 1500 to 2000 degrees Fahrenheit, this temperature being maintained from seven to ten days. The kiln then is closed, the fires are drawn, and the bricks are allowed to cool. This part of the process is called annealing, and to produce a tough brick requires from seven to ten days. The cooled bricks are sorted into different lots; the No. 1 paving bricks are generally found in the upper layers in the kiln.

Sizes. Two sizes of bricks are made: one size measuring $8\frac{1}{2}\times 2\frac{1}{2}\times 4$ inches weighing about 7 pounds and requiring 58 to the square yard. The other, measuring $8\frac{1}{2}\times 3\frac{1}{2}\times 4$ inches and frequently called "blocks", weighs about $9\frac{1}{2}$ pounds and requires 45 to the square yard.

Characteristics. The characteristics of brick suitable for paving are: not to be acted upon by acids—shale bricks not to absorb more than 2 per cent nor less than $\frac{1}{2}$ of 1 per cent of their weight of water, and clay bricks not to absorb more than 6 per cent of their weight of water (the absorption by a shale brick of less than $\frac{1}{2}$ of 1 per cent of its weight of water, indicates that it has been overburned); when broken with a hammer, to show a dense close-grained structure, free from lime, air holes, cracks, or marked laminations; not to scale,

spall, or chip, when quickly struck on the edges; hard but not brittle.

Tests for Paving Brick. To ascertain if brick possesses the required qualities they are subjected to three tests: (1) abrasion by impact (commonly called the "rattler" test); (2) absorption; (3) cross breaking.

The Rattler Test. The rattler is a steel barrel 28 inches long and 28 inches in diameter, the sides formed of 14 staves fastened to two cast-iron heads furnished with trunnions which rest in a cast-iron frame. It is provided with gears and a belt pulley arranged to revolve at a rate of from 29½ to 30½ revolutions per minute. The material employed to abrade the brick is spherical balls of cast iron, the composition of which is: combined carbon, not less than 2.50 per cent; graphitic carbon, not more than 0.10 per cent; silicon, not more than 1 per cent; manganese, not more than 0.50 per cent; phosphorus, not more than 0.25 per cent; sulphur, not more than 0.08 per cent. Two sizes of balls or shot are used, the larger being 3.75 inches in diameter when new and weighing about 7½ pounds, the smaller being 1.875 inches in diameter and weighing 0.95 pounds. A charge consists of ten large shot with enough small shot to make a weight of 300 pounds. The shot is used until the large size is worn to a weight of 7 pounds and the small shot is worn to a size that will pass through a circular hole 1¾ inches in diameter made in a cast-iron plate ¼-inch thick.

The brick to be tested are subjected to a temperature of 100 degrees Fahrenheit for three hours. Ten bricks are weighed and placed in the rattler with a charge of spherical shot, and the rattler is revolved for 1800 revolutions. The bricks then are taken out, pieces less than 1 pound in weight are removed and the balance weighed. From the weights before and after rattling the percentage of loss is calculated. The loss ranges from 16 per cent to 40 per cent. Brick to be used under heavy traffic should not lose more than 22 per cent, and for light traffic not more than 28 per cent.

Absorption Test. The absorption test is made on five bricks that have been through the rattler test. They are weighed, and are immersed in water for 48 hours, then are taken out and weighed, with the surplus water wiped off. From the weights before and after immersion the percentage of water absorbed is calculated.

Cross-Breaking Test. This test is made by placing a brick edge on supports 6 inches apart. The load is applied at the center of the brick, and is increased uniformly until fracture occurs. The average of the result on ten bricks is used in computing the modulus of rupture, $R=\frac{3WL}{2bd^2}$; in which W is the average breaking load in pounds, L the length between supports in inches, b the breadth, and d the depth in inches.

Brick-Pavement Qualifications. *Advantages.* The advantages of brick pavement may be stated as follows:

(1) Easy traction.
(2) Good foothold for horses.
(3) Not disagreeably noisy.
(4) Yields but little dust and mud.
(5) Adapted to all grades.
(6) Easily repaired.
(7) Easily cleaned.
(8) But slightly absorbent.
(9) Pleasing to the eye.
(10) Expeditiously laid.
(11) Durable under moderate traffic.

Defects. The principal defects of brick pavements arise from lack of uniformity in the quality of the bricks, and from the liability of incorporating in the pavement bricks too soft or too porous a structure, which crumbles under the action of traffic or frost.

Foundation. A brick pavement should have a firm foundation. As the surface is made up of small, independent blocks, each one must be supported adequately, or the load coming upon it may force it downwards and cause unevenness, a condition which conduces to the rapid destruction of the pavement. Several forms of foundation have been used—such as gravel, plank, sand, broken stone, and concrete. The last mentioned is the best.

Sand Cushion. The sand cushion is a layer of sand placed on top of the concrete to form a bed for the brick. Practice regarding the depth of this layer of sand varies considerably. In some cases it is only ½ inch deep, varying from this up to 3 inches. The sand cushion is very desirable, as it not only forms a perfectly true and even surface upon which to place brick, but also makes the

pavement less hard and rigid than would be the case were the brick laid directly on the concrete.

The sand is spread evenly, sprinkled with water, smoothed, and brought to the proper contour by screeds or wooden templets, properly trussed and mounted on wheels or shoes which bear upon the upper surface of the curb. Moving the templet forward levels and forms the sand to a uniform surface and proper shape.

The sand used for the cushion coat should be clean and free from loam, moderately coarse, and free from pebbles exceeding $\frac{1}{4}$ inch in size.

Manner of Laying. The bricks should be laid on edge or on one flat, as closely and compactly as possible, in straight courses across the street, with the length of the bricks at right angles to the axis of the street. Joints should be broken by at least 3 inches. None but whole bricks should be used, except in starting a course or making a closure. To provide for the expansion of the pavement, both longitudinal and transverse expansion joints are used, the former being made by placing a board templet $\frac{7}{8}$-inch thick against the curb and abutting the brick thereto. The transverse joints are formed at intervals varying between 25 and 50 feet, by placing a templet or building lath $\frac{3}{8}$-inch thick between two or three rows of brick. After the bricks are rammed and ready for grouting, these templets are removed, and the spaces so left are filled with coal-tar pitch or asphaltic paving cement. The amount of pitch or cement required will vary between 1 and $1\frac{1}{2}$ pounds per square yard of pavement, depending upon the width of the joints. After 25 or 30 feet of the pavement is laid, every part of it should be rammed with a rammer weighing not less than 50 pounds and the bricks which sink below the general level should be removed, sufficient sand being added to raise the brick to the required level. After all objectionable brick have been removed, the surface should be swept clean, then rolled with a steam roller weighing from 3 to 6 tons. The object of rolling is to bring the bricks to an unyielding bearing with a plane surface; if this is not done, the pavement will be rough and noisy and will lack durability. The rolling should be executed first longitudinally, beginning at the crown and working toward the gutter, taking care that each return trip of the roller covers exactly the same area as the preceding trip, so that the second

passage may neutralize any careening of the brick due to the first passage.

The manner of laying brick at street intersections is shown in Fig. 85.

Joint Fillings. The character of the material used in filling the joints between the brick has considerable influence on the success

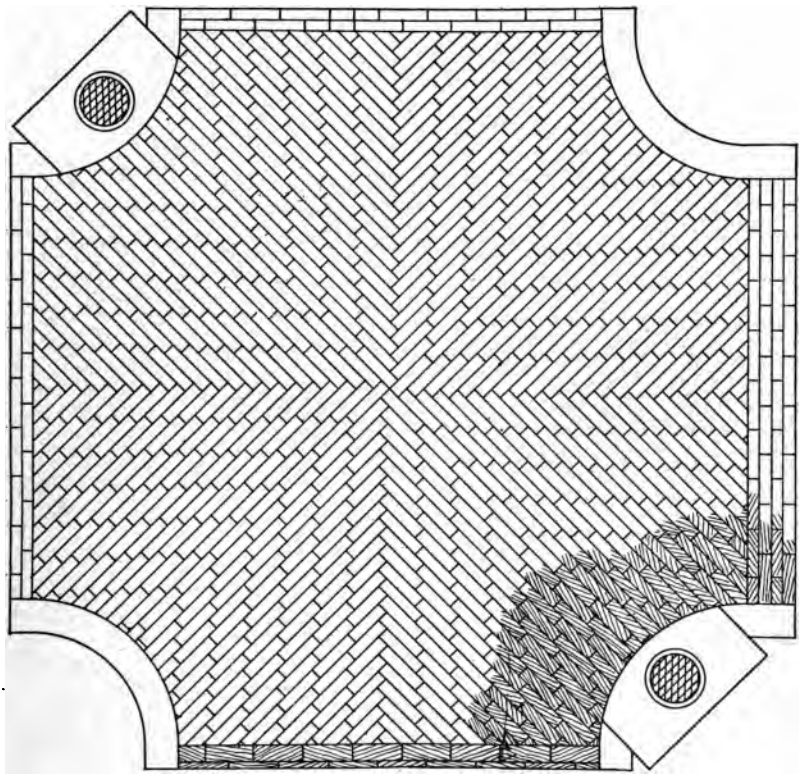


Fig. 85. Method of Laying Bricks at Street Intersections

and durability of the pavement. Various materials have been used—such as sand, coal-tar pitch, asphalt, mixtures of coal tar and asphalt, and Portland cement, besides various patented fillers, as "Murphy's grout", which is made from ground slag and cement. Each material has its advocates, and there is much difference of opinion as to which gives the best results.

The best results seem to be obtained by using a high grade of Portland cement containing the smallest amount of lime in its

composition; the presence of the lime increasing the tendency of the filler to swell through absorption of moisture, causing the pavement to rise or to be lifted away from its foundation, and thus producing the roaring or rumbling noise so frequently complained of.

The Portland-cement grout, when uniformly mixed and carefully placed, resists the impact of traffic and wears well with brick. When a failure occurs, repairs can be made quickly, and, if made early, the pavement will be restored to a good condition. If, however, repairs are neglected, the brick soon loosen and the pavement fails.

Fig. 86. Grout Box Used in Laying Brick Pavement
Courtesy of National Paving Brick Manufacturers Association, Cleveland, Ohio

The office of a filler is to prevent water from reaching the foundation, and to protect the edges of the brick from spalling under traffic. In order to meet both of these requirements, every joint must be filled to the top, and must remain so, wearing down with the brick. Sand does not meet these requirements. Although at first making a good filler, being inexpensive and reducing the liability of the pavement to be noisy, it soon washes out, leaving the edges of the brick unprotected and consequently liable to be chipped. Coal tar and the mixtures of coal tar and asphalt have an advantage in rendering a pavement less noisy and in cementing together any breaks that may occur through upheavals from frost or other causes;

but, unless made very hard, they have the disadvantage of becoming soft in hot weather and flowing to the gutters and low places in the pavement, there forming a black and unsightly scale and leaving the high parts unprotected. The joints, thus deprived of their filling, become receptacles for water, mud, and ice in turn; and the edges of the brick are broken down quickly. Some of these mixtures become so brittle in winter that they crack and fly out of the joints under the action of traffic.

The Portland-cement filler is prepared by mixing 2 parts of cement and 1 part of fine sand with sufficient water to make a thin grout. The most convenient arrangement for preparing and distributing the grout is a water-tight wooden box carried on four wood wheels about 12 inches in diameter, Fig. 86. The box may be about 4 feet wide, 7 feet long, and 12 inches deep, furnished with a gate about 8 inches wide, in the rear end. The box should be mounted on the wheels with an inclination, so that the rear end is about 4 inches lower than the front end.

Following are the successive operations of placing the filler: The cement and sand are placed in the box, and sufficient water is added to make a thin grout. The grouting box is located about 12 feet from the gutter, the end gate opened, and about 2 cubic feet of the grout allowed to flow out and run over the top of the brick (care being taken to stir the grout while it is being discharged), Fig. 87. If the brick are very dry, the entire surface of the pavement should be wet thoroughly with a hose before applying the grout; if not, absorption of the water from the grout by the bricks will prevent adhesion between the bricks and the cement grout. The grout is swept into the joints by ordinary bass brooms. After a length of about 100 feet of the pavement has been covered the box is returned to the starting point, and the operation is repeated with a grout somewhat thicker than the first. If this second application is not sufficient to fill the joints, the operation is repeated as often as may be necessary to fill them. If the grout has been made too thin, or the grade of the street is so great that the grout will not remain long enough in place to set, dry cement may be sprinkled over the joints and swept in. After the joints are filled completely and inspected, allowing three or four hours to intervene, the completed pavement should be covered with sand to a depth

Fig. 87. Street Laying Gang Applying Filler to Brick Pavement
Courtesy of National Paving Brick Manufacturers Association, Cleveland, Ohio

of about $\frac{1}{2}$ inch, and the roadway barricaded, and no traffic allowed on it for at least ten days.

The object of covering the pavement with sand is to prevent the grout from drying or settling too rapidly; hence, in dry and windy weather, it should be sprinkled from time to time. If coarse sand is employed in the grout, it will separate from the cement during the operation of filling the joints, with the result that many joints will be filled with sand and very little cement, while others will be filled with cement and little or no sand; thus there will be

Fig. 88. Coal-Tar Heating Tank
Courtesy of Barber Asphalt Paving Company, Philadelphia, Pennsylvania

many spots in the pavement in which no bond is formed between the bricks, and under the action of traffic these portions quickly will become defective.

The coal-tar filler is best applied by pouring the material from buckets, and brooming it into the joints with wire brooms; and in order to fill the joints effectually, it must be used only when very hot. To secure this condition, a heating tank on wheels is necessary, Fig. 88. It should have a capacity of at least 5 barrels, and be kept at a uniform temperature all day. One man is necessary to feed the fire and draw the material into the buckets; another, to carry

Fig. 89. Typical Brick Pavement Located in City. Eight Years Old When Picture Was Taken
Courtesy of National Paving Brick Manufacturers Association, Cleveland, Ohio

the buckets from the heating tank to a third, who pours the material over the street. The latter starts to pour in the center of the street, working backward toward the curb, and pouring a strip about 2 feet in width. A fourth man, with a wire broom, follows immediately after him, sweeping the surplus material toward the pourer and in the direction of the curb. This method leaves the entire surface of the pavement covered with a thin coating of pitch, which immediately should be covered with a light coating of sand, the sand becoming imbedded in the pitch. Under the action of traffic, this thin coating is worn away quickly, leaving the surface of the bricks clean and smooth, Fig. 89.

Tools Used by Hand in the Construction of Block Pavements. The principal tools required in constructing block pavements comprise *hammers* and *rammers* of varying sizes and shapes, depending on the material and size of the blocks to be laid; also *crowbars*, sand *screens*, and rattan and wire *brooms*. Cobblestones, square blocks, and brick require different types both of hammer and rammers for adjusting them to place and for forcing them to their seats. A cobblestone rammer, for example, is usually made of wood (generally locust) in the shape of a long truncated cone, banded with iron at top and bottom, weighing about 40 pounds, and having two handles, one at the top and another on one side. A Belgian-block rammer is slightly heavier, consisting of an upper part of wood set in a steel base; while a rammer for granite blocks is still heavier, comprising an iron base with cast-steel face, into which is set a locust plug with hickory handles. For laying brick, a wooden rammer shod with cast iron or steel and weighing about 27 pounds is used. A light rammer of about 20 pounds weight, consisting of a metallic base attached to a long, slim, wooden handle, is used for miscellaneous work, such as tamping in trenches, next to curbs, etc.

Concrete-Mixing Machine. Where large quantities of concrete are required, as in the foundations of improved pavements, concrete can be prepared more expeditiously and economically by the use of mechanical mixers, and the ingredients will be mixed more thoroughly than by hand. Thorough incorporation of the ingredients is an essential element in the quality of a concrete. When mixed by hand, however, the incorporation is rarely complete, because it

depends upon the proper manipulation of the hoe and shovel. The manipulation, although extremely simple, is rarely performed by the ordinary laborer as it should be unless he is watched constantly by the overseer.

Several varieties of concrete-mixing machines are in the market, all of which are efficient and of good design. A convenient portable

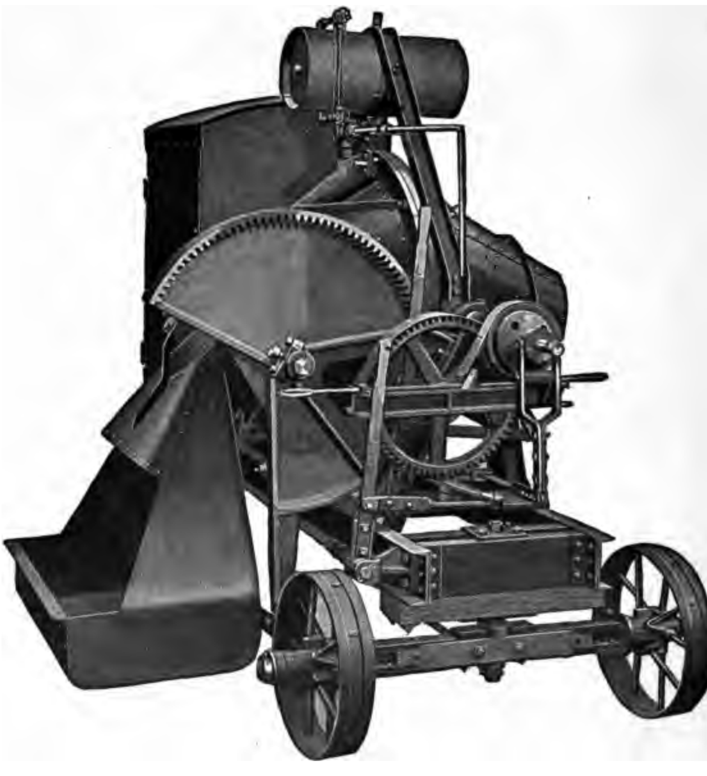


Fig. 90. Smith Concrete Mixer on Truck with Gasoline Engine, Power Charger, and Water Tank
Courtesy of T. L. Smith Company, Milwaukee, Wisconsin

type is illustrated in Fig. 90. The capacity of the mixers ranges from 5 to 20 cubic yards per hour, depending upon size, regularity with which the materials are supplied, speed, etc.

Gravel Heaters. A special type of oven usually is employed for heating the gravel used for joint filling in stone-block pavements. These heaters are made in various sizes, a common size being 9 feet long, 5 feet wide, and 3 feet 9 inches high.

WOOD-BLOCK PAVEMENTS

Wood-block pavements, Fig. 91, are formed of rectangular blocks measuring from 3½ to 4 inches wide, 5 to 10 inches long, and 4 inches deep, impregnated with creosote, or other preservative, laid in a bed of Portland-cement mortar spread upon a concrete foundation, with the joints between the blocks filled with either Portland-cement grout, or a bituminous filler.

The wood used is obtained from the long-leaved yellow pine (pinus palustrus), lob-lolly pine (pinus taeda), short-leaved pine (pinus echinata), Cuba pine (pinus heterophylla), black gum (nyssa sylvatica), red gum (liquidambar styrraciflua), Norway pine (pinus resinosa), or tamarack (larix laricina).

The wood should be cut from sound trees, free from cracks, shakes, and knots.

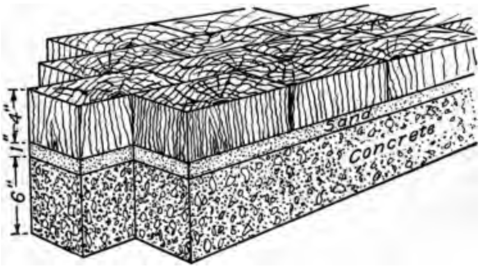


Fig. 91. Section Showing Foundation for Wood-Block Pavements and Method of Laying Blocks

The great enemy of wood pavement is decay due to a low form of plant life called fungi. The fungi attack the wood from the outside, and if the wood is in the right condition for the spores to grow, they ultimately will penetrate the entire structure of the wood. There are three classes of fungi: one which attacks all parts of the wood structure; another which attacks the cellulose; and a third, which is the most common, and attacks only the lignin—the name of the many organic substances that are incrusted around the cellulose, and which with the latter constitute the essential part of woody tissue—here the fungi dissolve the lignin and the cellulose to make food for their development. Heat, air, and moisture are necessary to the existence of the fungi; without any one of these elements they cannot live. To destroy the fungus life and preserve wood from decay many processes have been devised; the one that seems to meet the requirements better than any other is the process of creosoting.

Creosoting. This process consists in impregnating the wood with the dead oil of tar, called "creosote", from which the ammonia

has been removed. Its effect on the wood is to coagulate the albumen and thereby prevent its decomposition, also to fill the pores of the wood with a bituminous substance which excludes both air and moisture, and which is obnoxious to the lower forms of animal and vegetable life.

The coal-tar creosote oil is used without admixture or adulteration with other oils or tars. Its characteristics are: specific gravity, 1.03 to 1.08, at a temperature of 100 degrees Fahrenheit; contain not more than 5 per cent of tarry matter, nor more than 2 per cent of water, and not more than 8 per cent of tar acids, 99 per cent to be soluble in hot benzol; when subjected to distillation at gradually increasing temperatures up to 400 degrees Fahrenheit not more than 5 per cent of distillate shall pass over, at 450 degrees not more than 35 per cent, and up to 600 degrees Fahrenheit not more than 80 per cent; after complete distillation not more than 2 per cent of coke shall remain; upon sulphonating a sample of the total distillate, the residue shall not exceed 1 per cent.

For applying the creosote to the wood, several methods are followed. The one in most favor for paving blocks is the "pressure process", which essentially consists in: (1) steaming the wood for the purpose of liquefying the sap and other substances contained in the interfibrous spaces; (2) creating a vacuum for the purpose of removing the liquefied substances; (3) injecting the creosote under pressure.

The operation is performed in metal cylinders called "retorts", 6 or more feet in diameter and of any desired length, usually about 100 feet. The load of blocks, called a "charge", is placed upon metal cars called "buggies" and is run into the retort cylinder, the ends of which then are hermetically closed with "heads" or doors. Steam, at a gage pressure varying from 15 pounds to 45 pounds per square inch, is admitted to the retort (in some plants a vacuum is first created) and the pressure maintained for several hours. When the operator considers that the steaming has been continued a sufficient length of time, the products of condensation are removed from the retort through a blow-off cock in the bottom; when this is accomplished an air exhaust, or vacuum pump is put in operation, and a vacuum of from 20 inches to 26 inches is created and maintained for about one hour, at the end of which time the creosote is allowed

to flow into the retort until it is filled. A pressure pump then is started to force the creosote into the retort until the pressure reaches 100 pounds to 150 pounds per square inch. This pressure is maintained until the required amount of creosote has been injected in the wood, then the surplus is drawn off, the heads opened, and the charge withdrawn.

The amount of creosote injected into the wood varies from 10 pounds to 22 pounds per cubic foot of wood. The amount is determined primarily by measuring the tanks and is verified by testing sample blocks. A sample block is bored entirely through in the direction of the fiber with an auger 1 inch in diameter, the hole being located midway between the sides and about ⅓ the length of the block from one end. The borings are collected, thoroughly mixed, and the quantity and ratio of creosote to wood in the borings determined by extracting the creosote completely with carbon bisulphide.

The condition of the wood at the time of the treatment, is preferably dry and free from an excess of water. After treatment, and until used, the blocks during dry weather should be sprinkled frequently with water to prevent drying and cracking. The treated blocks are sometimes subjected to tests to determine the resistance to wear when saturated with water, the resistance to compression and impact, and to ascertain the amount of water the wood will absorb.

Laying the Blocks. The surface of the concrete foundation is cleansed from dust and dirt by sweeping, then sprinkled with water. Upon the cleaned surface a cushion coat is formed, by spreading a layer of sand 1 inch thick, Fig. 92, or a mortar composed of 1 part Portland cement and 2 parts sand, mixed with sufficient water to form a stiff paste (the practice of using a mixture of cement and sand slightly moistened with water produces a defective pavement). The blocks are set upon the cushion coat with the fiber vertical, Fig. 93, in straight, parallel courses at right angles to the axis of the street, except at intersections where they are set at an angle of 45 degrees with the axis of the street. They are laid so as to have the least possible width of joint (wide joints hasten the destruction of the wood by permitting the fibres to broom and wear under traffic). Blocks in adjoining courses break joint by at least 3 inches. At the

Fig. 92. Spreading Sand Foundation for Wood Blocks in LaSalle Street, Chicago
Courtesy of Engineering News, New York City

Fig. 93. Laying Wood Blocks in LaSalle Street, Chicago
Courtesy of Engineering News, New York City

Fig. 94. Wood-Block Pavement Being Hammered and Rolled, Preparatory to Putting in Filler
Courtesy of Engineering News, New York City

Fig. 95. Spreading Sand Filler on Wood-Block Pavement
Courtesy of Engineering News, New York City

curb it is customary to place one or two rows of blocks with the length parallel to the curb and $\frac{3}{4}$ inch therefrom.

After the blocks are laid they are brought to a uniform surface by ramming with hand rammers or rolling with a light steam roller, Fig. 94. When laid upon a mortar cushion, the rolling or ramming must be completed before the mortar sets.

In some cases the cushion coat is omitted, the surface of the concrete freed from dust by dry sweeping is covered with a thin coat of a bituminous cement and the blocks laid directly upon it. Sometimes, the side and one end of each block, when it is about to be set in place, are dipped in the same bituminous material that is used to cover the concrete, the blocks are placed in contact and the surface is covered with a thin coating of the bituminous material, this being covered with a layer of sand or fine gravel.

After the blocks have been brought to a uniform surface, the joints are filled with either fine sand, cement grout, or a bituminous cement, Fig. 95. When sand is used, it should be fine and dry, spread over the surface of the pavement, and swept about until the joints are filled. Cement grout is made of equal parts of Portland cement and fine sand mixed with water to the required consistency. It is spread over the surface of the blocks and swept into the joints until they are filled. The surface of the pavement then is covered with sand, and the grout is allowed to set for about seven days before traffic is admitted. The bituminous filler is composed of coal-tar pitch, asphalt, or combinations of these, and other ingredients. The filler is applied hot in the same manner as described under brick pavement. To provide for the expansion of the blocks the joint next the curb is filled with bituminous filler.

Qualifications of Wood Pavements. *Advantages.* The advantages of wood pavement may be stated as follows:

(1) It affords good foothold for horses.

(2) It offers less resistance to traction than stone, and slightly more than asphalt.

(3) It suits all classes of traffic.

(4) It may be used on grades up to 5 per cent.

(5) It is moderately durable.

(6) It yields no mud when laid upon an impervious foundation.

(7) It yields but little dust.

(8) It is moderate in first cost.

(9) It is not disagreeably noisy.

Defects. The principal objections to wood pavement are:

(1) It is difficult to cleanse.

(2) Under certain conditions of the atmosphere it becomes greasy and very unsafe for horses. This may be remedied by covering the surface with a thin layer of fine sand or gravel; a similar treatment will absorb the oil which exudes during warm weather.

(3) It is not easy to open for the purpose of gaining access to underground pipes, it being necessary to remove rather a large surface for this purpose, which has to be left a little time after being repaired before traffic again is allowed upon it.

ASPHALT PAVEMENTS

Sheet-Asphalt Pavement. Sheet asphalt is the name used to describe a pavement having a wearing surface composed of sand graded in predetermined proportions, of a fine material or filler, and of asphalt cement, all incorporated by mixing in a mechanical mixer, and laid upon a concrete foundation, the surface of the latter being covered with a thin layer of bituminous concrete called a "binder".

Asphalt Cement. This is prepared from solid bitumen, refined and fluxed with (1) the residuum from paraffine petroleum; (2) the residuum from asphaltic petroleum; (3) a mixture of paraffine and asphaltic petroleum residuums; (4) natural malthas, or is prepared from (5) solid residual bitumen produced in the distillation of asphaltic petroleums, and fluxed with residuum oil produced from the same material.

Refined asphalt is that freed from the combined water and accompanying inorganic and organic matter. By comparatively simple operations the several varieties of asphalt may be separated from their impurities. Two methods are employed for refining; one using steam and the other direct fire. In both methods the asphalt is placed in tanks and slowly heated until thoroughly melted, and during the melting the mass is agitated by a current of either air or dry steam. The method of using steam is superior to the fire method. In the latter method there always is danger of overheating, in addition to the formation of coke and the cracking of the hydrocarbons.

The varieties of asphalt known as gilsonite and grahamite, which are practically pure bitumen, do not require refining, but they are used to a very small extent in paving.

The greater part of the solid bitumen used for paving in the United States is obtained from the West Indies and South America. The more extensively used being that found at Trinidad, W. I., and at Bermudez, Venezuela. The asphalts known by the trade names "california" and "texaco" are produced by refining asphaltic oils, and may or may not require to be fluxed.

Fluxes are fluid oils and tars which are mixed with asphalt to produce a desired consistency. The refined asphalt is melted and the flux previously heated added to it, in the proportion required to produce the desired consistency. The mixture of asphalt and flux is agitated either by mechanical means or by a blast of air until the materials are thoroughly incorporated and the desired consistency is obtained.

Sand. The sand should be siliceous and so free from organic matter, mica, soft grains, and other impurities, that these will not amount to more than 2 per cent of its volume.

Fine Material or Filler. This consists of any sound stone, usually limestone or sand, pulverized to such fineness that the whole will pass the No. 50 sieve, and not more than 10 per cent will be retained on the No. 100 sieve, and at least 70 per cent will pass the No. 200 sieve. Portland cement sometimes is used instead of the pulverized stone.

The paving composition is prepared by heating the ingredients separately to a temperature between 300 and 350 degrees Fahrenheit, then incorporating them by mixing in a mechanical mixer. The hot sand is measured into the mixer, followed by the hot filler; these two materials are thoroughly mixed together, and the hot cement is added in such a way as to distribute it evenly over the mixed sand and filler; the mixing then is continued until the materials form a uniform and homogeneous mass, with the grains of sand completely covered with cement. A typical mixture is: sand 100 pounds; filler 17.5 pounds; bitumen in asphalt cement 17.5 pounds.

The proportions of the ingredients in the paving mixture are not constant, but vary with the climate of the place where the pavement is to be used, the character of the sand, and the amount

and character of the traffic that will use the pavement. The ranges are indicated in the following data:

Data for Asphaltic Paving

Asphaltic Paving Mixture.

Constituents	Per Cent
Asphalt cement	12 to 15
Sand	70 to 83
Stone dust	5 to 15

Weight of Material. A cubic yard of the prepared material weighs about 4500 pounds. One ton of refined asphaltum makes about 2300 pounds of asphalt cement, equal to about 3.4 cubic yards of surface material.

Wearing Surface per Cubic Yard of Material.

Thickness (inches)	Area (sq. yd.)
$2\frac{1}{2}$	12
2	18
$1\frac{1}{2}$	27

Laying the Pavement. The hot paving mixture is hauled to the street and dumped at a place outside of the space in which it

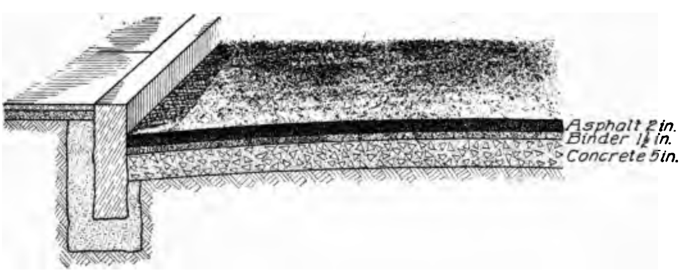


Fig. 96. Section of Asphalt Pavement Showing Layers

is to be laid. It then is thrown into place with hot shovels, and spread with hot rakes uniformly to such a depth as will give the required thickness when compacted. The finished thickness varies between $1\frac{1}{2}$ inches and 2 inches. The reduction of thickness by compression is about 40 per cent generally. Before the mixture is spread, the surfaces of curbs and street fittings that will be in contact with it are painted with hot asphalt cement.

The pavement is constructed in two forms: (1) The paving mixture is laid directly upon the surface of the concrete foundation;

(2) the surface of the concrete foundation is covered with a coat of asphaltic concrete, Fig. 96, called the "binder course", the object of which is to unite more securely the wearing surface to the foundation. This it does by containing a larger percentage of cement, which, if put in the surface mixture, would render it too soft. The binder is composed of sound, hard stone broken to pass a 1¼-inch screen, sand, pulverized stone, and asphalt cement, mixed in the desired proportions. A typical mixture is: stone 100 pounds; sand 40 pounds; stone dust 8 pounds; bitumen in asphalt cement 8 pounds.

The paving composition is compressed by means of rollers and tamping irons, the latter being heated in a fire contained in an iron basket mounted on wheels. These irons are used for tamping such portions as are inaccessible to the roller, namely, gutters, around manhole heads, etc.

Two rollers are sometimes employed; one, weighing 5 to 6 tons and of narrow tread, is used to give the first compression; and the other, weighing about 10 tons and of broad tread, is used for finishing. The rate of rolling varies; the average is about 1 hour for 1000 square yards of surface. After the primary compression, natural hydraulic cement, or any impalpable mineral matter, is sprinkled over the surface, to prevent the adhesion of the material to the roller and to give the surface a more pleasing appearance. When the asphalt is laid up to the curb, the surface of the portion forming the gutter is painted with a coat of hot cement.

Although asphaltum is a poor conductor of heat, and the cement retains its plasticity for several hours, occasions may and do arise through which the composition before it is spread has cooled; its condition when this happens is analogous to hydraulic cement which has taken a "set", and the same rules which apply to hydraulic cement in this condition should be respected in regard to asphaltic cement.

If the temperature of the air at the time of hauling is below 70 degrees Fahrenheit the wagons carrying it are covered with canvas or other material to prevent the loss of heat. The temperature when delivered at the place where it is to be used must not be less than 280 degrees Fahrenheit.

Two methods are followed in laying an asphalt pavement adjoining street railway tracks: (1) a course of granite-block or brick paving is laid between the rail and the edge of the asphalt; (2) the asphalt is laid directly against the rail, which, if its temperature is below 50 degrees Fahrenheit, is heated by suitable apparatus to a temperature of about 60 degrees Fahrenheit immediately before the asphalt is laid.

Foundation. A solid, unyielding foundation is indispensable with all asphaltic pavements, because asphalt of itself has no power of offering resistance to the action of traffic, consequently it nearly always is placed upon a bed of hydraulic-cement concrete. The concrete must be set thoroughly and its surface dry before the asphalt is laid upon it; if not, the water will be sucked up and converted into steam, with the result that coherence of the asphaltic mixture is prevented, and, although its surface may be smooth, the mass is really honeycombed, so that as soon as the pavement is subjected to the action of traffic, the voids or fissures formed by the steam appear on the surface, and the whole pavement is broken up quickly.

Qualifications of Asphalt Pavements. *Advantages.* These may be summed up as follows:

(1) It gives easy traction.

(2) It is comparatively noiseless under traffic.

(3) It is impervious.

(4) It is easily cleansed.

(5) It produces neither mud nor dust.

(6) It is pleasing to the eye.

(7) It suits all classes of traffic.

(8) There is neither vibration nor concussion in traveling over it.

(9) It is laid expeditiously, thereby causing little inconvenience to traffic.

(10) Openings to gain access to underground pipes are easily made.

(11) It is durable.

(12) It is repaired easily.

Defects. These are as follows:

(1) It is slippery under certain conditions of the atmosphere.

The American asphalts are much less so than the European, on account of their granular texture derived from the sand. The difference is very noticeable; the European are as smooth as glass,

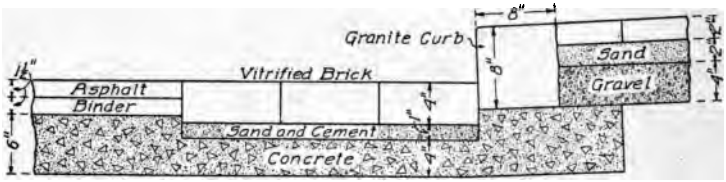


Fig. 97. Section of Asphalt Pavement Showing Use of Vitrified Brick to Form Gutter

while the American resemble fine sandpaper. The slipperiness can be decreased by heating the surface of the pavement with a surface heater, then applying a layer of coarse sand and rolling it into the surface.

(2) It will not stand constant moisture, and will disintegrate if sprinkled excessively.

(3) Under extreme heat it is liable to become so soft that it will roll or creep under traffic and present a wavy surface; and under extreme cold there is danger that the surface will crack and become friable.

(4) It is not adapted to grades steeper than 2½ per cent, although it is in use on grades up to 7.30 per cent.

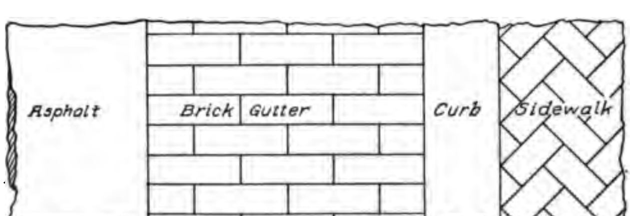


Fig. 98. Plan of Asphalt Pavement Showing Use of Vitrified Brick to Form Gutter

(5) Repairs must be made quickly, for the material has little coherence, and if, from irregular settlement of foundation or local violence, a break occurs, the passing wheels rapidly shear off the sides of the hole, and it soon assumes formidable dimensions.

Although pure asphaltum is impervious absolutely and insoluble in either fresh or salt water, yet asphalt pavements in the continued presence of water are quickly disintegrated. Ordinary rain or daily sprinkling does not injure them when they are allowed to become perfectly dry again. The damage is most apparent in gutters and adjacent to overflowing drinking fountains. This defect has long been recognized, and various measures have been taken to overcome it, or at least reduce it to a minimum. In some cities, ordinances have been passed, seeking to regulate the sprinkling of the streets; and in many places the gutters are laid with stone or vitrified brick, Figs. 97 and 98, while in others the asphalt is laid to the curb, a space of 12 to 15 inches along the curb being covered with a thin coating of asphalt cement.

Failure of Asphalt Pavement. The failure of asphalt pavement is due to any one, or a combination, of the following causes:

(1) *Unsuitable Materials.* The asphalt may be changed so by natural causes as to possess little or no cementing power. The fluxing agent may form only a mechanical instead of a chemical union with the asphalt, or its character may be such as to render the asphalt brittle, in which condition it easily is broken up under traffic. The sand may be graded improperly, either too coarse or too fine, or contain loam, vegetable matter, or clay.

(2) *Improper Manipulation.* The crude asphalt may have been refined at too high a temperature, which reduces or destroys the cementing property. The cement may be of improper consistence, of insufficient quantity, or inadequately mixed. If the cement is too hard, the pavement will have a tendency to crack during cold weather; and if too soft, it will push out of place and form waves under traffic. The quantity of cement needed varies with the character of the sand—a fine sand requires more cement than a coarse one, and the proportion of cement must be varied to suit the sand. When the ingredients are mixed inadequately, the cement and the particles of sand are not brought into intimate contact. Free oil or an excess of asphalt in the binder, making it too rich, is liable to work up and be absorbed by the wearing surface, and thus cause it to disintegrate. The mixture may be chilled while being transported from the plant to the street. There may be separation of the cement and sand, for if the distance from

the plant to the street is great and there is any delay, some of the cement may work to the bottom of the load, and when it is dumped, there will be fat and lean spots, both of which are injurious. The paving mixture may be laid upon a damp or dirty foundation. There may be inadequate compression, for the importance of thorough compaction is not appreciated always and this portion of the work is slighted frequently.

(3) *Natural Causes.* All materials in nature continually are undergoing change due to the action of the elements, and to this asphalt is not an exception. Subjected to the action of heat, all bitumens grow harder, and when the maximum degree of hardness is attained, natural decay sets in so that under the combined action of the elements, the material gradually rots and disintegrates.

(4) *Defective Foundation.* By unequal settlement a weak foundation will cause cracks and depressions in the surface which will enlarge speedily under traffic. A porous foundation will permit the ground water to rise, by capillary action, to the underside of the wearing surface, where by freezing it will cause cracks and thus provide access for surface water; non-watertight connection between curbs and street fittings also furnishes a path for surface water to reach the underside of the wearing surface, where the presence of water causes rapid decay.

(5) *Other Causes.* Illuminating gas, escaping from leaking pipes under the pavement causes disintegration of the asphalt. Contraction, caused by the decrease in cementing power through aging of the asphalt, results in cracks. Due to an excess of fluxing material, there may be rolling and waving of the pavement under traffic. Injury may be caused by fires made upon the pavement, or by oil droppings from motor vehicles.

Sheet asphalt pavement usually is constructed under a contract that provides for its maintenance during a period of years (five or ten) by the contractor. Such a contract stipulates that the condition of the pavement at the expiration of the maintenance or guarantee period shall be as follows: Surface free from depressions exceeding $\frac{3}{4}$-inch deep, when measured between any two points 4 feet apart on a line conforming substantially to the original contour of the pavement. Free from cracks. Contain no disintegrated

material. Thickness not reduced more than $\frac{3}{4}$ inch. Foundation free from cracks and settlement.

Rock Asphalt Pavement. This is the name applied to pavement made from the limestones and sandstones found naturally impregnated or cemented with bitumen. They are prepared for use by crushing and heating, and are used in their natural condition or mixed with other materials. Deposits are found in many parts of the United States and Europe. In Europe, rock asphalt is the material most extensively used for paving, under the name "asphalte". The European rock asphalts are impregnated very uniformly with from 7 per cent to 14 per cent of asphalt, and readily compact into a hard, smooth pavement which in frosty latitudes becomes very slippery. The American rock asphalts are impregnated irregularly with from 5 per cent to 30 per cent of asphalt. Their use for paving is limited, chiefly owing to the cost of transportation.

Asphalt Blocks. *Formation.* Asphalt paving blocks are formed from a mixture of asphaltic cement and crushed stone in the proportion of 8 or 12 per cent of cement to 88 or 92 per cent of stone. The materials are heated to a temperature of about 300° Fahrenheit, and mixed while hot in a suitable vessel. When the mixing is complete, the material is placed in molds and subjected to heavy pressure, after which the blocks are cooled suddenly by plunging into cold water. The usual dimensions of the blocks are 4 inches wide, 3 inches deep, and 12 inches long.

Foundation. The blocks usually are laid upon a concrete foundation with a cushion coat of sand about $\frac{1}{2}$-inch thick. They are laid with their lengths at right angles to the axis of the street, and the longitudinal joints should be broken by a lap of at least 4 inches. The blocks then are rammed with hand hammers, or are rolled with a light steam roller, the surface being covered with clean, fine sand; no joint filling is used, as, under the action of the sun and traffic, the blocks soon become cemented.

The advantages claimed for a pavement of asphalt blocks over those for a continuous sheet of asphalt are: (1) that they can be made at a factory located near the materials, whence they can be transported to the place where they are to be used and can be laid by ordinary paviors, whereas sheet pavements require special

machinery and skilled labor; (2) that they are less slippery, owing to the joints and the rougher surface due to the use of crushed stone.

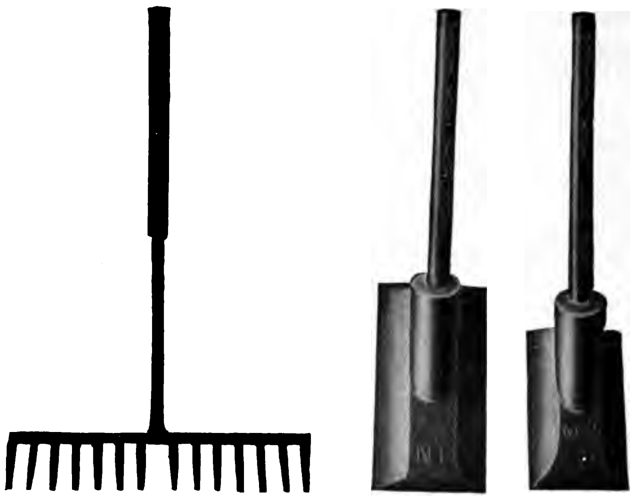


Fig. 99. Rake and Smoothing Irons Used in Laying Asphalt Pavement
Courtesy of Barber Asphalt Paving Company, Philadelphia, Pennsylvania

Another Form. Another form of asphalt block, known as the "Lueba" block, consists of a block 8¾ inches long, 4½ inches wide, and 4 inches thick, with the lower 3 inches composed of Portland-cement concrete covered with 1 inch of natural-rock asphalt; the two materials being joined under heavy hydraulic pressure. The blocks are laid on a concrete foundation and the joints between them are filled with hydraulic-cement grout.

Fig. 100. Pouring Pots Used with Asphalt Pavements
Courtesy of Barber Asphalt Paving Company

Tools Employed in Construction of Asphalt Pavements. The tools used in laying sheet-asphalt pavements comprise hand rammers iron, rakes, smoothing irons, Fig. 99; pouring pots, Fig. 100; hand rollers, either with or without a fire pot, Fig. 101; and steam rollers, with or without provision for heating the front roll, Fig. 102. These

rollers are different in construction, appearance, and weight from those employed for compacting broken stone. The difference is due to the different character of the work required.

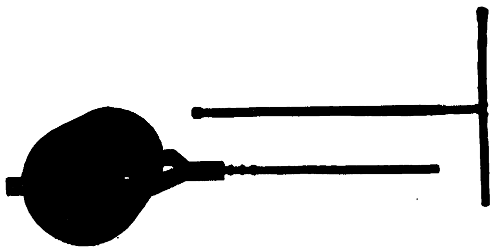


Fig. 101. Hand Rollers Used in Laying Asphalt Pavements
Courtesy of Barber Asphalt Paving Company, Philadelphia, Pennsylvania

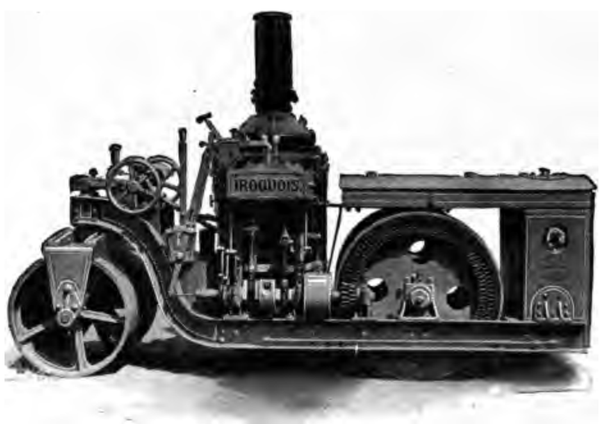


Fig. 102. Small Road Roller Used in Laying Asphalt Pavements
Courtesy of Barber Asphalt Paving Company, Philadelphia, Pennsylvania

The principal dimensions of the 5-ton roller are as follows:

Front roll or steering wheel, diameter	30 to 32 inches
Real roll or driving wheel, diameter	48 inches
Front roll, width	40 inches
Rear roll, width	40 inches
Length, extreme	14 feet
Height, extreme	7 to 8 feet
Water capacity	80 to 100 gallons
Coal capacity	200 pounds

MISCELLANEOUS PAVEMENTS

Under this head will be described briefly the most notable examples of pavements devised as substitutes for the recognized standard types, and sometimes used where good materials are not available, or where insufficient funds prevent their purchase, and in some cases for the purpose of utilizing waste products.

Burnt Clay. In the Mississippi Valley, during the dry season, the clay is cut from the roadway to a depth of about 2 feet, and piled so as to form enclosures about 15 feet in diameter and 2 feet high. After remaining so for about ten days to dry out, a fire is made in the inclosure, more dry clay placed on top and the burning proceeded with. The burnt clay after cooling, is relaid upon the road, and then, being of a thoroughly porous nature, settles into a dry, solid layer.

Straw. Clay roads have been improved by shaping and harrowing the road, then applying a layer of wheat straw, which is moistened with water, and cut and mixed with the clay by a disk harrow. More straw is added and the operation repeated, then compacted with a steam roller. The treatment is applied twice a year.

Oyster-Shell. The shells are spread on the road previously shaped and rolled. They crush readily and, possessing a high cementing quality, bind together to form a compact, smooth road surface, but owing to their softness, they are quickly ground to powder which is carried away readily by wind and rain water.

Chert. The siliceous material found overlying the red sandstone, which forms the covering of the red hematite iron ore in some of the Southern States, is used for both street and road paving. It is laid directly upon the earth surface or upon a prepared foundation, sprinkled, and compacted in the same manner as water-bound macadam.

Slag. The slag produced in the manufacture of iron and steel is used in various ways for paving. (1) It may be crushed to the desired sizes and used in the same manner as broken stone, laid in one or two courses, sprinkled and rolled. In some cases, a binder composed of quicklime is used; in others, a waste sulphite liquor is mixed with the water used for moistening it before rolling; and in others, it is mixed with coal-tar or other bituminous cement

and formed into a pavement in the same manner as bituminous macadam. The pavement called "tarmac", a large amount of which has been used in England, is composed of slag, coal tar, rosin, and Portland cement. (2) The slag may be formed into blocks by casting in molds, which are used in the same manner as stone blocks. In this form they are called "scoria" or "slag" blocks.

Clinker. Where crematories are employed for the destruction of garbage about 33 per cent of the material remains after burning, in the form of clinker. This is broken up and ground to a fine powder, mixed with either a hydraulic or a bituminous cement, and pressed into blocks and slabs.

Petrolithic. Petrolithic paving is made by applying a bituminous oil to earth, sand, gravel, clay, or loam roads. The soil is plowed to a depth of at least 6 inches, pulverized by harrowing, and sprinkled with water. The bituminous oil is applied in one or two coats at the rate of 1 gallon per square yard, the oil and soil are mixed and compacted by a roller weighing 5000 pounds, the surface of which is studded with spikes having a flat head measuring 2×3 inches, and on which account it is named a "sheep's-foot" roller. In operation, the spikes or feet are forced into the loose soil and compress or pack it from the bottom upwards. After a thorough mixing and tamping, the surface is shaped with a road grader and rolled with a roller of the ordinary form.

Kleinpflaster. Kleinpflaster is the name given to a stone pavement used in Germany for exceptionally heavy traffic, and used also in England, under the name "durax". It is made of 3-inch cubes of hard stone, cut by machinery, and laid in small segments of circles. The stones are laid as close as possible and the joints are filled with hydraulic-cement grout or bituminous filler.

Iron. Several experiments have been made with iron for paving, but, while eminently durable, it was rough, noisy, and slippery, and its use either alone or combined with other materials has been abandoned.

Trackways. Formed of stone slabs, brick, concrete blocks, steel, and other materials, trackways have been constructed at various times for the purpose of reducing the resistance to traction. Their use on an extensive scale, however, has been abandoned except in Italy, Spain, and Germany.

National Pavement. National pavement is composed of pulverized clay, loam, or ordinary soil, heated and mixed with liquid bitumen. The mixture is spread to a depth of 2 or 3 inches upon the surface of the compacted and drained natural soil and is compressed by a power roller.

Fibered Asphalt Pavement. Fibered asphalt pavement is composed of wood fiber, obtained as a waste product from the process of extracting tannin and asphalt. The fiber is heated and mixed with a predetermined quantity of asphalt. The hot mixture is run into molds forming small blocks which are shipped to the place of use. The blocks are there heated to a temperature of 275° F. in a traveling heater that moves along the roadway and from which the hot mixture emerges in a continuous stream 18 inches wide and is deposited on the previously prepared foundation to a depth of 4 inches. After spreading, it is compressed to a thickness of 2 inches with a power roller.

Westrumite. Westrumite is an asphalt cement temporarily liquefied by emulsification. It is mixed cold with broken stone in an ordinary concrete mixer, spread on the foundation, and compacted by rolling. The evaporation of the vehicle leaves the asphalt cement as the binder.

MISCELLANEOUS STREET WORK

FOOTPATHS

A footpath or walk is simply a road under another name—a road for pedestrians instead of one for horses and vehicles. The only difference that exists is in the degree of service required; but the conditions of construction that render a road well adapted to its object are very much the same as those required for a walk.

The effects of heavy loads such as traverse carriage-ways are not felt upon footpaths; but the destructive action of water and frost is the same in either case, and the treatment to counteract or resist these elements as far as practicable, and to produce permanency, must be the controlling idea in each case, and should be carried out upon a common principle. It is not less essential that a walk should be well adapted to its object than that a road should be; and it is annoying to find it impassable or insecure and

in want of repair when it is needed for convenience or pleasure. In point of economy, there is the same advantage in constructing a footway skilfully and durably as there is in the case of a road.

Width. The width of footwalks (exclusive of the space occupied by projections and shade trees) should be ample to accommodate comfortably the number of people using them. In streets devoted entirely to commercial purposes, the clear width should be at least one-third the width of the carriage-way; in residential and suburban streets, a very pleasing result can be obtained by making the walk one-half the width of the roadway, and by devoting the greater part to grass and shade trees.

Cross Slope. The surface of footpaths must be sloped so that the surface water will readily flow to the gutters. This slope need not be very great; $\frac{1}{8}$ inch per foot will be sufficient. A greater slope with a thin coating of ice upon it, becomes dangerous to pedestrians.

Foundation. As in the case of roadways, so with footpaths, the foundation is of primary importance. Whatever material may be used for the surface, if the foundation is weak and yielding, the surface will settle irregularly and become extremely objectionable, if not dangerous, to pedestrians.

Surface. The requirements of a good covering for sidewalks are:

(1) It must be smooth but not slippery.

(2) It must absorb the minimum amount of water, so that it may dry rapidly after rain.

(3) It must not be abrased easily.

(4) It must be of uniform quality throughout, so that it may wear evenly.

(5) It must neither scale nor flake.

(6) Its texture must be such that dust will not adhere to it.

(7) It must be durable.

Materials. The materials used for footpaths are as follows: stone, natural and artificial; wood; asphalt; brick; tar concrete; and gravel.

Stones. Of the natural stones, sandstone (bluestone) and granite are employed extensively. The bluestone, when well laid, forms an excellent paving material. It is of compact texture, absorbs water to a very limited extent, and hence soon dries after rain; it has sufficient hardness to resist abrasion, and wears well

without becoming excessively slippery. Granite, although exceedingly durable, wears very slippery, and its surface has to be roughened frequently.

Slabs, of whatever stone, must be of equal thickness throughout their entire area; the edges must be dressed true to the square for the whole thickness (edges must not be left feathered as shown

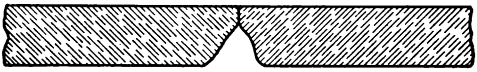


Fig. 103. Faulty Joint in Stone Sidewalk

in Fig. 103); and the slabs must be bedded solidly on the foundation and the joints filled with cement mortar. Badly set or faultily dressed flagstones are very unpleasant to walk over, especially in rainy weather; the unevenness causes pedestrians to stumble, and rocking stones squirt dirty water over their clothes.

Wood. Wood has been used largely in the form of planks; it is cheap in first cost, but proves very expensive from the fact that it lasts but a comparatively short time and requires constant repair to keep it from becoming dangerous.

Asphalt. Asphalt forms an excellent footway pavement; it is durable and does not wear slippery.

Brick. Brick of suitable quality, well and carefully laid on a concrete foundation, makes an excellent footway pavement for residential and suburban streets of large cities, and also for the main streets of smaller towns. The bricks should be good qualities of paving brick (ordinary building brick are unsuitable, as they soon wear out and are broken easily). The bricks should be laid in parallel rows on their edges, with their lengths at right angles to the axis of the path.

Concrete. Concrete or artificial stone is used extensively as a footway paving material. Its manufacture is the subject of several patents, and numerous kinds are to be had in the market. When manufactured of first-class materials and laid in a substantial manner, with proper provision against the action of frost, artificial stone forms a durable, agreeable, and inexpensive pavement.

Concrete walks are formed in one or two courses. In one-course work, the concrete is laid to a depth of 4 inches and tamped until sufficient mortar flushes to the surface to permit the forming of a smooth surface. In two-course work, the concrete for the base is spread and tamped to a depth of 3 inches, the top or surface course is spread upon the base before the latter has begun to set. The top course has a thickness of about 1 inch, and it is tamped and its surface is brought to the required plane by a straightedge and by troweling. Expansion is provided for by transverse joints extending the full depth of the concrete. The joints are placed 4 feet apart and are formed by placing across the side forms a $\frac{1}{4}$-inch thick metal dividing strip, which is removed before the cement sets so that the edges of the joint may be smoothed and rounded with a suitable tool.

The area to be covered by the walk is excavated to a minimum depth of 8 inches, or to such greater depth as the nature of the ground may require to secure a solid foundation. The surface of the ground so exposed is compacted by ramming, and a drainage course is formed of broken stone, gravel, or steam-plant cinders, thoroughly compacted by ramming, and its surface is brought to a plane parallel to and 4 inches below the finished surface of the concrete. In some situations it may be necessary to connect the drainage course with the sewers, street drains, or side ditches, for the purpose of furnishing an outlet for standing water; this is done by the use of 3-inch drain pipe placed where required.

The forms of steel or wood should be made substantially, and left in place until the concrete is set hard.

Concrete walks fail from the use of improper materials and defective workmanship, insufficient expansion joints, heaving and cracking by frost, due to imperfect drainage, displacement and cracks, due to settlement of the drainage course—this latter being frequent when cinders are used, as in time they are liable to decompose and shrink in volume and thus allow the concrete to settle. In two-course work failure may be in respect to flaking of the surface by the action of water and frost entering between and separating the courses. The concrete should not be laid during freezing weather, nor should frozen materials be used in the work.

CURBSTONES AND GUTTERS

Curbstones. Curbstones are employed for the outer side of footways, to sustain the covering and to form the gutter. Their upper edges are set flush with the footwalk pavement, so that the water can flow over them into the gutters

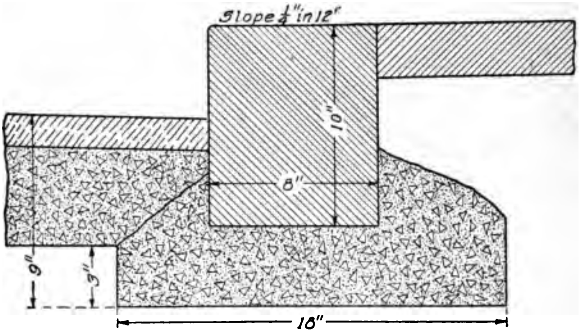


Fig. 104. Typical Section Showing Stone Curb Eight Inches Thick

The disturbing forces which the curb has to resist are: (1) The pressure of the earth behind it, which is frequently augmented by piles of merchandise, building materials, etc. This pressure tends to overturn it, break it transversely, or move it bodily on its base. (2) The pressure due to the expansion of freezing earth behind

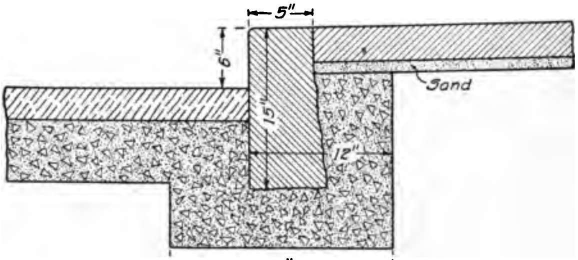


Fig. 105. Typical Section Showing Stone Curb Five Inches Thick

and beneath the curb. This force is most frequent where the sidewalk is sodded partly and the ground accordingly is moist. Successive freezing and thawing of the earth behind the curb will occasion a succession of thrusts forward, which, if the curb be of faulty design, will cause it to incline several degrees from the vertical.

(3) The concussions and abrasions caused by traffic. To withstand the destructive effect of wheels, curbs are faced with iron; and a concrete curb with a rounded edge of steel has been patented and used to some extent. Fires built in the gutters deface and seriously injure the curb. Posts and trees set too near the curb, tend to break, displace, and destroy it.

The use of drain tiles under the curb is a subject of much difference of opinion among engineers. Where the subsoil contains water naturally, or is likely to receive it from outside the curb lines, the use of drains is of decided benefit; but great care must be exercised in jointing the draintiles, lest the soil shall be loosened and removed, causing the curb to drop out of alignment.

The materials employed for curbing are the natural stones—as granite, sandstone (bluestone), etc.; artificial stone—fire clay, and cast iron.

The dimensions of curbstones vary considerably in different localities and according to the width of the footpaths; the wider the path, the wider should be the curb. However, it should be never less than 8 inches deep, nor narrower than 4 inches. Depth is necessary to prevent the curb's turning over toward the gutter. It never should be in smaller lengths than 3 feet. The top surface should be beveled off to conform to the slope of the footpath. The front face should be hammer-dressed for a depth of about 6 inches, in order that there may be a smooth surface visible against the gutter. The back for 3 inches from the top also should be dressed, so that the flagging or other paving may butt fair against it. The end joints should be cut a true square the full thickness of the stone at the top, and so much below the top as will be exposed; the remaining portion of the depth and bottom should be squared roughly, and the bottom should be fairly parallel to the top. (See Figs. 104 and 105.)

Combination Curb and Gutter. Concrete curb and gutter combined is constructed by placing the concrete in suitable forms. The concrete should be handled so as to prevent the separation of the stone and mortar, and when placed should be tamped well to bring the mortar to the surface and make complete contact with the forms. The corner formed by the top and face surfaces is rounded to a radius of about 1½ inches; sometimes this corner is

formed of a steel bar put in place before the concrete is laid and anchored by metal strips spaced about 3 feet apart. Expansion joints are formed at distances of 10 or 12 feet. The remarks made under concrete walks regarding foundation, drainage, failure, etc., apply also to concrete curbs.

STREET CLEANING

The cleaning of streets is practiced for the purpose of protecting the health of the neighboring residents and for the comfort of the users. It is of comparatively recent development, and is rendered possible only by the use of hard pavements. The materials

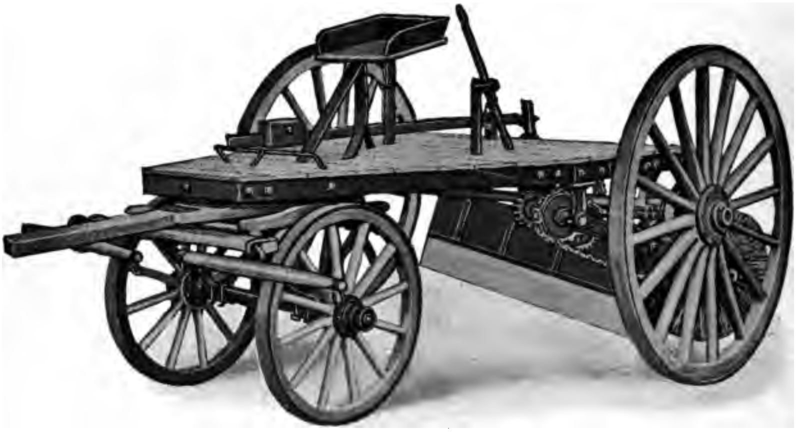


Fig. 106. Typical Machine Street Sweeper
Courtesy of Acme Road Machinery Company, Frankfort, New York

to be removed from the streets consist of animal droppings, material worn from the pavement, materials dropped from vehicles, waste from building construction, miscellaneous materials swept from houses, stores, and factories, and the accumulation of snow during winter.

Cleaning Methods. The local conditions and character of the traffic and pavement determine the methods to be employed and the intervals for cleaning the streets. The methods employed are: sweeping, either by hand or by machine brooms; and flushing with water—the work being performed either during the day or the night, by large gangs at night, and by means of a patrol system during the day. Fig. 106 shows one of the machine sweepers used.

TABLE XV

Rate and Cost of Street Cleaning

Pavement	Approximate Surface Swept per Man (sq. yds. per hr.)		Approximate Dirt from Daily Sweeping (cu. yds. per 1000 sq. yds.)		Average Cost per Each Cleaning (cents per sq. yd.)
	(Wet)	(Dry)	(Min.)	(Max.)	
Asphalt	1000	1200	.007	.040	.0030
Granite-block	750	1000	.015	.024	.0050
Macadam (water-bound)	700		.100	.350	.0106
Wood			.070	.200	.0070
Brick					.0034

In the hand-cleaning method by day patrol, each man is furnished with a push broom, shovel, and can carrier in which to place the refuse, and has a certain section of street to clean each day. The day patrol sometimes is supplemented by a large gang working during the night. When machine brooms are employed they usually are operated at night and are supplemented by the patrol system during the day. As to which is the most economical, it will depend upon the cost of labor and the condition of the pavements; on pavements covered with ruts and depressions machine brooms are ineffective.

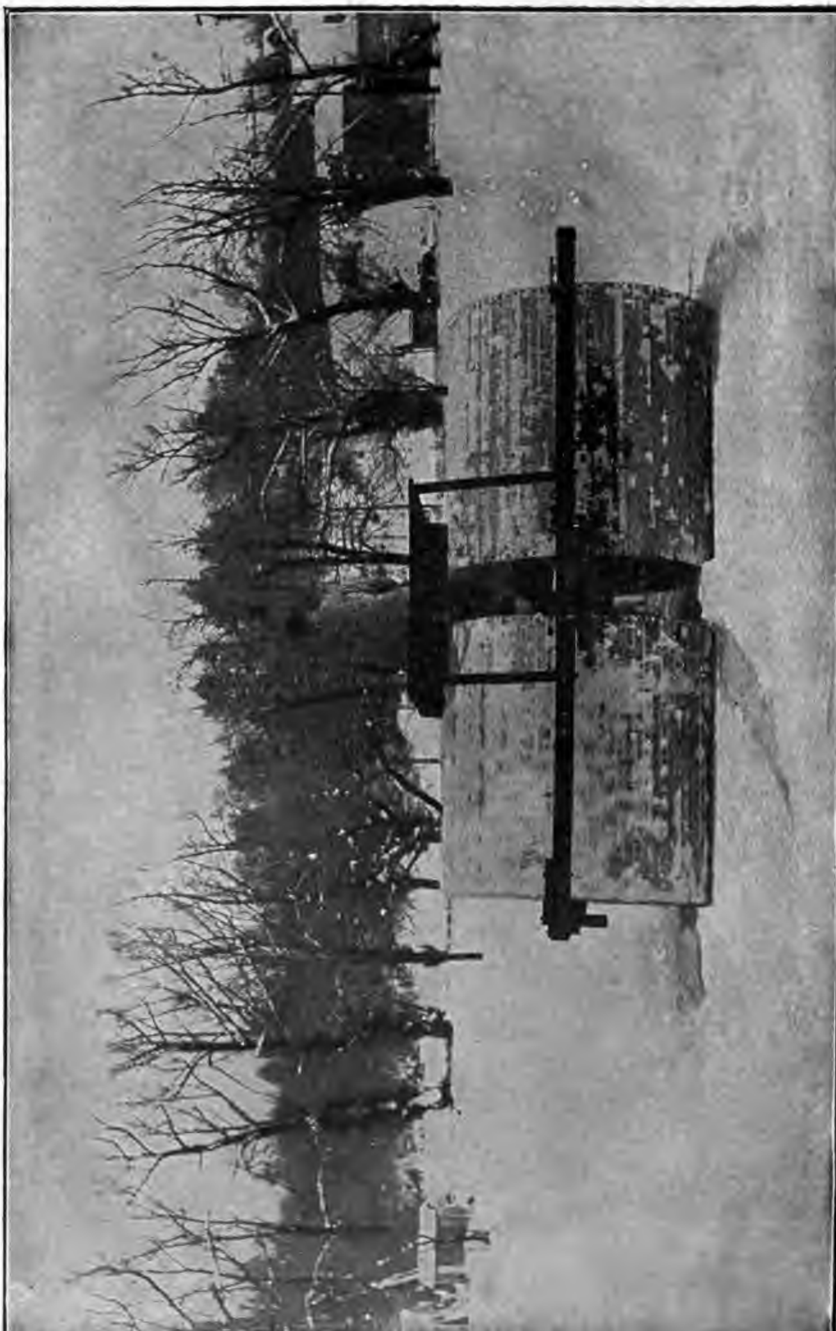
The approximate costs of the various methods of street cleaning per 1000 sq. yds. are:

Sweeping (hand)	$0.281
Sweeping (machine)	0.317
Flushing (hand-hose)	0.319
Flushing (machine)	0.721

The average cost of supervision varies from .011 cent to 34 cents per mile.

The amount of surface cleaned by a machine broom depends upon the width of the broom, the power of the horses or other motive power, gradient, and condition of the surface. The wider the broom the less will be the cost. The average speed of travel is about $1\frac{1}{2}$ miles per hour.

In Table XV are indicated the amount of surface which an average man will sweep per hour, depending upon the condition of the pavement—dry, wet, or muddy; relative amount of dirt



produced by the different pavements, if swept daily; and the average cost of cleaning different pavements.

Removal of Snow. The methods employed for keeping roads and streets passable during the period of snowfall varies according to the climatic conditions. In localities subject to heavy falls of snow, and continuous low temperature that retards the melting of the snow until spring, two methods are followed: (1) a narrow track is opened by a snowplow, through the center of the road, the snow being formed into long, narrow heaps on each side; (2) the snow is not removed, but is compacted by rolling with a light-weight wood or metal roller, Fig. 107. In localities having light falls and in the larger cities, the snow is pushed by plows or rotary brooms toward the gutters from where it is loaded into vehicles, hauled to a natural waterway and dumped, or in the absence of this it is placed in vacant lots and in some cases it is disposed of by dumping into the sewers through the manholes, but this must be done carefully, as there is liability of choking the sewer by the snow's consolidating. Light falls may be disposed of by the application of a stream of water to the surface of the street thereby washing the snow into the sewer. Many machines have been devised for melting the snow by the application of steam, hot air, etc., but none of them have been successful economically. In some cities the snow is melted by an application of rock salt which produces a thawing action when mixed with the snow by the traffic, the slushy mixture so formed is swept to the gutters by machine brooms and washed into the sewers by a stream of water from the hydrants. Objection is made to this method on account of the intense cold produced and its injurious effect upon the feet of pedestrians and on the hoofs of horses.

In order to cause the minimum of inconvenience to traffic it is necessary that the snow be removed from the streets as quickly as possible, therefore, it is customary, before the arrival of winter, to lay out the method and organization required and to make arrangements for the quick mobilization of the force needed for its removal. To accomplish this the city is divided into districts, in each of which there is established a headquarters and depot stocked with the necessary tools to execute the work in that district, and to which the laborers report when the snow commences to fall.

Street Sprinkling. Streets and roads are sprinkled with water for the purpose of abating dust and cooling the air. While water-bound macadam and earth surfaces must be sprinkled to abate the dust, a stone-block, brick, asphalt, or wood pavement will not require sprinkling if thoroughly cleansed and kept clean. On unclean and badly maintained pavements, sprinkling with water as usually performed converts the fine dust into a slime which renders all smooth pavements slippery, and in warm weather it becomes a prolific breeding place for disease germs, it clings to the feet and clothing of pedestrians, and, with its accompanying germs, is carried into buildings and dwellings.

The average cost of sprinkling per square yard is $0.009.

The systems followed for executing the work of street cleaning, snow removal, and sprinkling are: (1) by contract where the contractor furnishes all the tools and labor; (2) by contract for the labor only, the city furnishing the tools and machinery; (3) by the city, with its own staff and machinery.

SELECTING THE PAVEMENT

The problem of selecting the best pavement for any particular case is a local one, not only for each city, but also for each of the various parts into which the city is imperceptibly divided; and it involves so many elements that the nicest balancing of the relative values for each kind of pavement is required in arriving at a correct conclusion.

In some localities, the proximity of one or more paving materials determines the character of the pavement; while in other cases a careful investigation may be required in order to select the most suitable material. Local conditions always should be considered; hence it is not possible to lay down any fixed rule as to what material makes the best pavement.

Qualifications. The qualities essential to a good pavement may be stated as follows:

(1) It should be impervious.

(2) It should afford good foothold for horses and adhesion for motor vehicles.

(3) It should be hard and durable, so as to resist wear and disintegration.

(4) It should be adapted to every grade.

(5) It should suit every class of traffic.
(6) It should offer the minimum resistance to traction.
(7) It should be noiseless.
(8) It should yield neither dust nor mud.
(9) It should be cleaned easily.
(10) It should be cheap.

Interests Affected. Of the above requirements, numbers (2), (4), (5), and (6) affect the traffic and determine the cost of haulage by the limitations of loads, speed, and wear and tear of horses and vehicles. If the surface is tough or the foothold bad, the weight of the load a horse can draw is decreased, thus necessitating the making of more trips or the employment of more horses and vehicles to move a given weight. A defective surface necessitates a reduction in the speed of movement and a consequent loss of time; it increases the wear of horses, thus decreasing their life service and lessening the value of their current services; it also increases the cost of maintaining vehicles and harness.

Requirements, numbers (7), (8), and (9), affect the occupiers of adjacent premises, who suffer from the effect of dust and noise; they also affect the owners of said premises, whose income from rents is diminished where these disadvantages exist. Numbers (3) and (10) affect the taxpayers alone—first, as to the length of time during which the covering remains serviceable; and second, as to the amount of the annual repairs. Number (1) affects the adjacent occupiers principally on hygienic grounds. Numbers (7) and (8) affect both traffic and occupiers.

Problem Involved in Selection. The problem involved in the selection of the most suitable pavement consists of the following factors: (1) adaptability; (2) desirability; (3) serviceability; (4) comparative safety; (5) durability; (6) cost.

Adaptability. The best pavement for any given roadway will depend altogether on local circumstances. Pavements must be adapted to the class of traffic that will use them. The pavement suitable for a road through an agricultural district will not be suitable for the streets of a manufacturing center; nor will the covering suitable for heavy traffic be suitable for a pleasure drive or for a residential district.

General experience indicates the relative fitness of the several

TABLE XVI

Resistance to Traction on Different Pavements

Kind of Pavement	Tractive Resistance	
	Lb. per Ton	Fraction of the Load
Sheet-asphalt	30 to 70	$\frac{1}{67}$ to $\frac{1}{30}$
Brick	15 to 40	$\frac{1}{133}$ to $\frac{1}{50}$
Cobblestone	50 to 100	$\frac{1}{40}$ to $\frac{1}{20}$
Stone-block	30 to 80	$\frac{1}{67}$ to $\frac{1}{25}$
Rectangular wood-block	30 to 50	$\frac{1}{67}$ to $\frac{1}{40}$
Round wood-block	40 to 80	$\frac{1}{50}$ to $\frac{1}{25}$

materials as follows: for country roads, suburban streets, and pleasure drives—broken stone; for streets having heavy and constant traffic—rectangular blocks of stone, laid on a concrete foundation, with the joints filled with bituminous or Portland-cement grout; for streets devoted to retail trade, and where comparative noiselessness is essential—asphalt, wood, or brick. More recent experience indicates that concrete, when properly laid and reinforced at necessary points, may be employed to advantage for any pavement, both as base and as wearing surface.

Desirability. The desirability of a pavement is its possession of qualities which make it satisfactory to the people using and seeing it. Between two pavements alike in cost and durability, people will have preferences arising from the condition of their health, personal prejudices, and various other intangible influences, causing them to select one rather than the other in their respective streets. Such selections often are made against the demonstrated economies of the case, and usually in ignorance of them. Whenever one kind of pavement is more economical and satisfactory to use than is any other, there should not be any difference of opinion about securing it, either as a new pavement or in the replacement of an old one.

The economic desirability of pavements is governed by the ease of movement over them, and is measured by the number of horses or pounds of tractive force required to move over them a given weight—usually 1 ton. The resistance offered to traction by different pavements is shown in Table XVI.

Serviceability. The serviceability of a pavement is its quality of fitness for use. This quality is measured by the expense caused to the traffic using it—namely, the wear and tear of horses and vehicles, loss of time, etc. No statistics are available from which to deduce the actual cost of wear and tear.

The serviceability of any pavement in great measure depends upon the amount of foothold afforded by it to the horses—provided, however, that its surface be not so rough as to absorb too large a percentage of the tractive energy required to move a given load over it. Cobblestones afford excellent foothold, and for this reason are largely employed by horse-car companies for paving between the rails; but the resistance of their surface to motion requires the expenditure of about 40 pounds of tractive energy to move a load of 1 ton. Asphalt affords the least foothold; but the tractive force required to overcome the resistance it offers to motion is only about 30 pounds per ton.

Comparative Safety. The comparison of pavements in respect to safety, is the average distance traveled before a horse falls. The materials affording the best foothold for horses are as follows, stated in the order of their merit:

(1) Earth, dry and compact.
(2) Gravel.
(3) Broken stone (macadam).
(4) Wood.
(5) Sandstone and brick.
(6) Asphalt.
(7) Granite blocks.

Durability. The durability of pavement is that quality which determines the length of time during which it is serviceable, and does not relate to the length of time it has been down. The only measure of durability of a pavement is the amount of traffic tonnage it will bear before it becomes so worn that the cost of replacing it is less than the expense incurred by its use.

As a pavement is a construction, it necessarily follows that there is a vast difference between the durability of the pavement and the durability of the materials of which it is made. Iron is eminently durable; but, as a paving material, it is a failure.

The durability of a paving material will vary considerably with

TABLE XVII

Terms of Life of Various Pavements

Materials	Terms of Life (Years)
Granite-block	12 to 30
Sandstone	6 to 12
Asphalt	10 to 14
Wood	7 to 15
Limestone	1 to 3
Brick	5 to 15
Macadam	5 to ?

the condition of cleanliness observed. One inch of overlying dirt will protect the pavement most effectually from abrasion, and prolong its life indefinitely. But the dirt is expensive; it injures apparel and merchandise, and is the cause of sickness and discomfort. In the comparison of different pavements, no traffic should be credited to the dirty one. The life or durability of different pavements under like conditions of traffic and maintenance, may be taken as shown in Table XVII.

Cost. First cost or the cost of construction, is largely controlled by the locality of the place, its proximity to the particular material used, and the character of the foundation. The question of cost is the one which usually interests taxpayers, and is problably the greatest stumblingblock in the attainment of good roadways. The first cost usually is charged against the property abutting on the highway to be improved. The result is that the average property owner always is anxious for a pavement that costs little, because he must pay for it, not caring for the fact that cheap pavements soon wear out and become a source of endless annoyance and additional expense. Thus false ideas of economy usually have stood, and undoubtedly always will stand to some extent, in the way of realizing that the best is the cheapest.

The pavement which has cost the most is not always the best; nor is that which cost the least the cheapest; the one which is truly the cheapest is the one which makes the most profitable returns in proportion to the amount expended upon it. No doubt there is a limit of cost to go beyond which would produce no practical benefit; but it always will be found more economical to spend enough

to secure the best results, and this always will cost less in the long run. One dollar well spent is many times more effective than one-half of the amount injudiciously expended in the hopeless effort to reach sufficiently good results. The cheaper work may look as well as the more expensive, for a time, but very soon may have to be done over again.

Economic Benefit. The economic benefit of a good roadway is comprised in the following: its cheaper maintenance, the greater facility it offers for traveling, thus reducing the cost of transportation; the lower cost of repairs to vehicles, and less wear of horses, thus increasing their term of serviceability and enhancing the value of their present service; the saving of time; and the ease and comfort afforded to those using the roadway.

Relative Economies. The relative economies of pavements—whether of the same kind in different condition, or of different kinds in like good condition—are determined sufficiently by summing their cost under the following headings of account:

(1) Annual interest upon first cost and sinking fund.

(2) Annual expense for maintenance.

(3) Annual cost for cleaning and sprinkling.

(4) Annual cost for service and use.

(5) Annual cost for consequential damages.

Interest on First Cost. The first cost of a pavement, like any other permanent investment, is measurable for purposes of comparison by the amount of annual interest on the sum expended. Thus, assuming the worth of money to be 4 per cent, a pavement costing $4 per square yard entails an annual interest loss or tax of $0.16 per square yard.

Cost of Maintenance. Under this head must be included all outlays for repairs and renewals which are made from the time when the pavement is new and at its best to a time subsequent, when, by any treatment, it is put again in equally good condition. The gross sum so derived, divided by the number of years which elapse between the two dates, gives an annual average cost for maintenance.

Maintenance means the keeping of the pavement in a condition practically as good as when first laid. The cost will vary considerably depending not only upon the material and the manner in

which it is constructed, but upon the condition of cleanliness observed, and the quantity and quality of the traffic using the pavement.

The prevailing opinion that no pavement is a good one unless, when once laid, it will take care of itself, is erroneous; there is no such pavement. All pavements are being worn constantly by traffic and by the action of the atmosphere; and if any defects which appear are not repaired quickly, the pavements soon become unsatisfactory and are destroyed. To keep them in good repair, incessant attention is necessary, and is consistent with economy. Yet claims are made that particular pavements cost little or nothing for repairs, simply because repairs in these cases are not made, while any one can see the need of them.

Cost of Cleaning and Sprinkling. Any pavement, to be considered as properly cared for, must be kept dustless and clean. While circumstances legitimately determine in many cases that streets must be cleaned at daily, weekly, or semiweekly intervals, the only admissible condition for the purpose of analysis of street expenses must be that of like requirements in both or all cases subjected to comparison.

The cleaning of pavements, as regards both efficiency and cost, depends (1) upon the character of the surface; (2) upon the nature of the materials of which the pavements are composed. Block pavements present the greatest difficulty; the joints can never be perfectly cleaned. The order of merit as regards facility of cleansing, is: (1) asphalt, (2) concrete, (3) brick, (4) stone, (5) wood, (6) macadam.

Cost of Service and Use. The annual cost for service is made up by combining several items of cost incidental to the use of the pavement for traffic—for instance, the limitation of the speed of movement, as in cases where a bad pavement causes slow driving and consequent loss of time; or cases where the condition of a pavement limits the weight of the load which a horse can haul, and so compels the making of more trips or the employment of more horses and vehicles; or cases where conditions are such as to cause greater wear and tear of vehicles, of equipment, and of horses. If a vehicle is run 1500 miles in a year, and its maintenance cost $30 a year, then the cost of its maintenance per

mile traveled is 2 cents. If the value of a team's time is, say \$1 for the legitimate time taken in going 1 mile with a load, and in consequence of bad roads it takes double that time, then the cost to traffic from having to use that mile of bad roadway is \$1 for each load. The same reasoning applies to circumstances where the weight of the load has to be reduced so as to necessitate the making of more than one trip. Again, bad pavements lessen not only the life service of horses, but also the value of their current service.

Cost for Consequential Damages. The determination of consequential damages arising from the use of defective or unsuitable pavements, involves the consideration of a wide array of diverse circumstances. Rough-surfaced pavements, when in their best condition, afford a lodgment for organic matter composed largely of the urine and excrement of the animals employed upon the roadway. In warm and damp weather, these matters undergo putrefactive fermentation, and become the most efficient agency for generating and disseminating noxious vapors and disease germs, now recognized as the cause of a large part of the ills afflicting mankind. Pavements formed of porous materials are objectionable on the same, if not even stronger, grounds.

Pavements productive of dust and mud are objectionable, and especially so on streets devoted to retail trade. If this particular disadvantage be appraised at so small a sum per lineal foot of frontage as \$1.50 per month, or 6 cents per day, it exceeds the cost of the best quality of pavement free from these disadvantages.

Rough-surfaced pavements are noisy under traffic and insufferable to nervous invalids, and much nervous sickness is attributable to them. To all persons interested in nervous invalids, this damage from noisy pavements is rated as being far greater than would be the cost of substituting the best quality of noiseless pavement; but there are, under many circumstances, specific financial losses, measurable in dollars and cents, dependent upon the use of rough, noisy pavements. They reduce the rental value of buildings and offices situated upon streets so paved—offices devoted to pursuits wherein exhausting brain work is required. In such locations, quietness is almost indispensable, and no question about the cost of a noiseless pavement weighs against its possession.

TABLE XVIII

Comparative Rank of Pavements

Characteristics: Qualities	Value (per cent)	Variety: Asphalt (sheet)	Asphalt (block)	Concrete	Macadam (bituminous)	Macadam (water-bound)	Brick	Granite	Sandstone	Wood
Low tractive resistance	20	20.0	19.0	18.0	19.0	11.0	18.0	12.0	14.0	20.0
Service on grades	10	3.0	3.0	7.0	4.0	8.0	9.0	10.0	10.0	2.0
Non-slipperiness	5	1.5	2.5	4.0	2.5	4.5	3.5	3.5	5.0	2.0
Favorableness to travel	5	5.0	4.5	3.5	4.0	4.5	3.5	3.5	4.0	4.5
Sanitariness	10	10.0	9.0	7.0	8.0	3.0	8.0	6.0	7.0	9.0
Noiselessness	3	2.5	2.5	2.0	2.5	2.5	1.5	1.0	1.5	3.0
Minimum dust	3	2.5	2.5	2.0	2.0	1.0	2.0	1.5	2.0	2.0
Ease of cleaning	5	5.0	5.0	3.5	4.0	1.0	3.5	1.5	1.5	5.0
Acceptability	4	3.5	3.5	2.5	3.0	1.5	2.5	2.0	2.5	4.0
Durability	15	7.5	8.5	6.0	3.0	1.5	10.0	15.0	14.0	11.5
Ease of maintenance	5	3.5	4.0	3.0	3.0	2.5	4.0	4.5	5.0	5.0
Cheapness (first cost)	10	4.5	4.0	5.0	7.5	10.0	4.0	3.0	3.5	3.0
Low annual cost	5	1.5	2.5	3.0	3.5	1.0	4.5	5.0	5.0	5.0
Totals.	100	70.0	70.5	66.5	66.0	52.0	74.0	68.5	75.0	76.0
Approximate first cost (dollars per sq. yd.).		2.30	2.65	1.85	1.35	1.00	2.65	3.25	3.00	3.45

When an investigator has done the best he can to determine such a summary of costs of a pavement, he may divide the amount of annual tonnage of the street traffic by the amount of annual costs, and know what number of tons of traffic are borne for each cent of the average annual cost, which is the crucial test for any comparison, as follows:

(1) Annual interest upon first cost and sinking fund. . . . . . .$
(2) Average annual expense for maintenance and renewal. .
(3) Annual cost for custody (sprinkling and cleaning). . . . . .
(4) Annual cost for service and use. . . . .
(5) Annual cost for consequential damages. . . . .
Amount of average annual cost . . . .
Annual tonnage of traffic. . . . .
Tons of traffic for each cent of cost. . . . .

Gross Cost of Pavements. Since the cost of a pavement depends upon the material of which it is formed, the width of the

roadway, the extent and nature of the traffic, and the condition of repair and cleanliness in which it is maintained, it follows that in no two streets is the endurance or the cost the same, and the difference between the highest and lowest periods of endurance and amount of cost is very considerable.

Comparative Rank of Pavements. In Table XVIII is given the rank of the various pavements in percentage, prorated from the values assigned in the first column to the desired qualities. The pavement ranking first in any given quality is given the full value for that quality, the others grading down from this value according to the extent to which they possess the desired quality. An examination of the table shows macadam to be the cheapest; least durable, and most difficult to maintain and cleanse; rather favorable to travel; comparatively low in sanitariness; and high in annual cost. While the table may be used as an aid in determining the most suitable pavement according to the factors that are susceptible of a numerical value, the values assigned must be modified by local conditions; first cost will necessarily vary in different localities, and certain factors will be more important in one locality than another.

Specifications. A specification or detailed description of the various works to be carried out always is attached to a contract, and is prepared before estimates are called for. The prominent points that are essential to the production of a specification that will fulfill its purpose properly, are: (1) description of the work; (2) extent of the work; (3) quality of the materials; (4) tests for the materials; (5) delivery of the materials; (6) character of the workmanship; (7) manner of executing the work.

Attention to these points and a clear and accurate description of each detail (leaving nothing to be imagined) not only will contribute materially to the rapid and efficient execution of the work, but will avoid any future misunderstanding. Every item of the work should be allotted a separate clause, for confusion must ensue when a single clause includes descriptions of several matters.

As a rule it is undesirable to insert in specifications any dimensions or weights that can be shown on the drawings. However, when it is necessary to insert them, words should be used instead

of numerals; the use of numerals, and particularly decimal numbers, should be avoided, as there is a risk of having them set up incorrectly by the typesetter and overlooked in the proofreading. When a numeral is used it should be followed by the word or words indicating the numeral, placing the numeral in parenthesis.

Brevity, so far as it is consistent with completeness, should prevail, but the word "et cetera" should be excluded rigidly, and the matters covered by it should be defined clearly. Neither should important points of the work be dismissed with the direction that "the work shall be done to the satisfaction of the engineer". A direction of this kind usually implies that the engineer does not know what he wants, and therefore leaves the matter to the superior knowledge of the contractor—an attitude not very creditable to the former. The only really legitimate use of this phrase is in a general clause referring to the whole of the work.

The specifying of impracticable sizes of materials must be avoided as it causes unnecessary discussion and frequently leads to a charge for "extras".

A clause or phrase permitting the furnishing of alternative materials or workmanship should be excluded, because such permission affords ground for dispute and difference of opinion. On the other hand, specifying that certain articles manufactured by a particular firm shall be used should be avoided, as it suggests unfairness on the part of the engineer, and may create the idea that his selection is not without profit to himself.

With regard to the actual methods of carrying out the work, the contractor should not be tied to any particular means of effecting the required end, unless special circumstances require it, for, provided the materials and workmanship are satisfactory, it is better to allow the contractor to use his own discretion as to the manner of producing the required result.

While the standard and proper tests for the materials always should be stipulated, yet if they are carried to an extreme degree, as frequently happens, they defeat their own object. When it becomes impossible to carry out certain unreasonable demands, the alternative is to evade them as much as possible; and it must be borne in mind that the more stringent the demand, the greater the difficulty in enforcing it.

Contracts. A good, clear, and comprehensive contract is a difficult thing to write, but it should be "common sense" from beginning to end, and should be the joint production of both engineering and legal ability, neither sacrificing the one feature to the other.

The stipulations of the contract form the legal part of the document and are distinct from the technical description of the work to be done. The essential points are: (1) time of commencement; (2) time of completion; (3) manner and times of payment; (4) prices for which the work is to be performed; (5) measurements; (6) damages for noncompletion; (7) protection of persons and property during the prosecution of work; (8) such special stipulations as may be required for the particular work that is being contracted for.

It should be borne in mind that the contract and specifications when duly signed by the parties interested, is a legal document, which must be produced in court in the event of a dispute arising, therefore, it is of the utmost importance that it be written clearly in simple language, the clauses being arranged in logical sequence, and the descriptions made exact and complete without being needlessly verbose.

High-sounding phrases, and duplication of statements or information, should be avoided as tending to confusion. Specifications are seldom judged by literary standards of excellence, therefore, words may be repeated again and again if they express the meaning of the writer more clearly and forcibly than an alternative would do.

In the case of a lengthy contract and specification, a complete index with the clause and page numbers will be found an aid to finding quickly any required subject; cross references may sometimes be introduced with advantage.

EXAMINATION PAPER

HIGHWAY CONSTRUCTION

PART II

Read Carefully: Place your name and full address at the head of the paper. Any cheap, light paper like the sample previously sent you may be used. Do not crowd your work, but arrange it neatly and legibly. *Do not copy the answers from the Instruction Paper; use your own words, so that we may be sure you understand the subject.*

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1. What are the advantages of granite-block pavement?
2. Draw a section showing proper construction of stone-block pavement.
3. What are the essentials of a good foundation?
4. What are the important conditions to bear in mind in fixing grades?
5. What substitutes may be used for pavement in country districts where funds are insufficient for constructing street pavements?
6. What are the disturbing forces that the curb has to resist?
7. What should comprise the essentials of a set of specifications?
8. What qualities are essential to a good pavement?
9. What are the essential points in a contract?
10. What are the materials generally used for foot paths?
11. Give the methods used for making roads passable during the period of snow fall.
12. What are the advantages claimed for asphalt blocks in comparison with a continuous sheet of asphalt?
13. Discuss the laying of asphalt pavement.
14. What governs the waterproof qualities of stone-block pavements?
15. What are the advantages of asphalt pavement?
16. How is the drainage of streets taken care of?